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HUMAN

PHYSIOLOGY;

ILLUSTRATED BY ENGRAVINGS.

BY

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WITH NUMEROUS ADDITIONS AND MODIFICATIONS.

IN TWO VOLUMES.

VOL. II.

PHILADELPHIA:

CAREY, LEA & BLANCHARD.

1836.

CONTENTS OF VOL. II.

H. T. Coulter.

HUMAN PHYSIOLOGY.

ABSORPTION.

In the consideration of the preceding functions we have seen the alimentary matter subjected to various actions and alterations; and, at length, in the small intestine, possessed of the necessary physical constitution for the chyle to be separated from it. Into the mode in which this separation,—which we shall find is not simply a secerning action, but one of elaboration and of a vital character,—is effected, we have now to inquire. It belongs to the function of *absorption*, and its object is to convey the nutritive fluid, formed from the food, into the torrent of the circulation.

Absorption is not, however, confined to the formation of this fluid. Liquids can pass into the blood directly through the coats of the containing vessel, without having been subjected to any elaboration; and the different constituents of the organs are constantly subjected to the absorbing action of vessels, by which their decomposition is effected, and their elements are conveyed into the blood; whilst antagonizing vessels, called *exhalants*, deposit fresh particles, in the place of those that are removed. Yet these various substances,—bone, muscle, hair, nail, as the case may be,—are never found, in their compound state, in the blood; and the inference, consequently, is, that at the very radicles of these absorbents and exhalants, the substance, on which absorption or exhalation has to be effected, is reduced to its primary constituents, and this by an action, to which we know nothing similar in physics or chymistry: hence, it has been inferred, the operation is one of the acts of vitality.

All the various absorptions may be classed under two heads:—the *external* and the *internal;* the former including those, that take place on extraneous matters from the surface of the body or from its prolongation—the mucous membranes; and the latter, those that are effected internally, on matters proceeding from the body itself, by removing parts already deposited.

By some physiologists, the action of the air in respiration has been referred to the former of these; and the whole function of absorption has been defined; the aggregate of actions, by which

nutritive substances—external and internal—are converted into fluids, which serve as the basis of arterial blood.

The function of respiration will be investigated separately. Our attention will, at present, be directed to the other varieties, and, first of all, to that which occurs in the digestive tube.

SECT. I.—DIGESTIVE ABSORPTION.

The absorption, effected in the organs of digestion, is of two kinds; according as it concerns liquids of a certain degree of tenuity, or solid food. The former, it has been remarked, are subjected to no digestive action, but disappear chiefly from the stomach, and the remainder from the small intestine; whilst the latter undergo conversion, before they are fitted to be taken up from the intestinal canal.

I. ABSORPTION OF CHYLE OR CHYLOSIS.

Anatomy of the Chyliferous Apparatus.

In the lower animals, absorption is effected over the whole surface of the body, both as regards the materials necessary for the nutrition of the body, and the supply of air. No distinct organs for the performance of these functions are perceptible. In the upper classes of animals, however, we find an apparatus, manifestly intended for the absorption of chyle, and constituting a vascular communication between the small intestine and the left subclavian. Along this channel, the chyle passes, to be emptied into that venous trunk.

The chyliferous apparatus consists of the chyliferous vessels, mesenteric glands and thoracic duct. The *chyliferous vessels* or *lacteals*, arise from the inner surface of the small intestine; in the villi, which are at the surface of, and between, the valvulæ conniventes. Their origin is, however, imperceptible, even by the aid of the microscope; and, accordingly, the nature of their arrangement has given occasion to much diversity of sentiment amongst anatomists. Lieberkühn affirms that, by the microscope, it may be shown, that each villus terminates in an *ampullula* or oval vesicle, which has its apex perforated by lateral orifices, through which the chyle enters. The doctrine of open mouths of lacteals and lymphatics has been embraced by Hewson, Sheldon, Cruikshank, and by many of the anatomists and physiologists of the present day; but, on the other hand, it has been contested by Mascagni and others; whilst Rudolphi and Meckel believe, that the lacteals have not free orifices in the cavity of the intestine; but that in the villi, in which absorption is effected, a spongy or sort of gelatinous tissue exists which accomplishes absorption, and, being continuous with the chyliferous vessels, conveys the product of absorption into them. Bichat conceived them to commence by a kind of sucker or absorbing

mouth, the action of which he compared to that of the puncta lachrymalia or of a leech or cupping-glass; and lastly,—from the observation, often made, that different coloured fluids, with which the lymphatics have been injected, have never spread themselves, either in the cellular tissue, or in the parenchyma of the viscera, Mojon, of Genoa, believes, that the lymphatics have no patulous orifice, and that they take their origin from a cellular filament, which progressively becomes a villosity, an areolar spongiole, a capillary, and, at length, a lymphatic trunk;—the absorbent action of these vessels being a kind of imbibition.

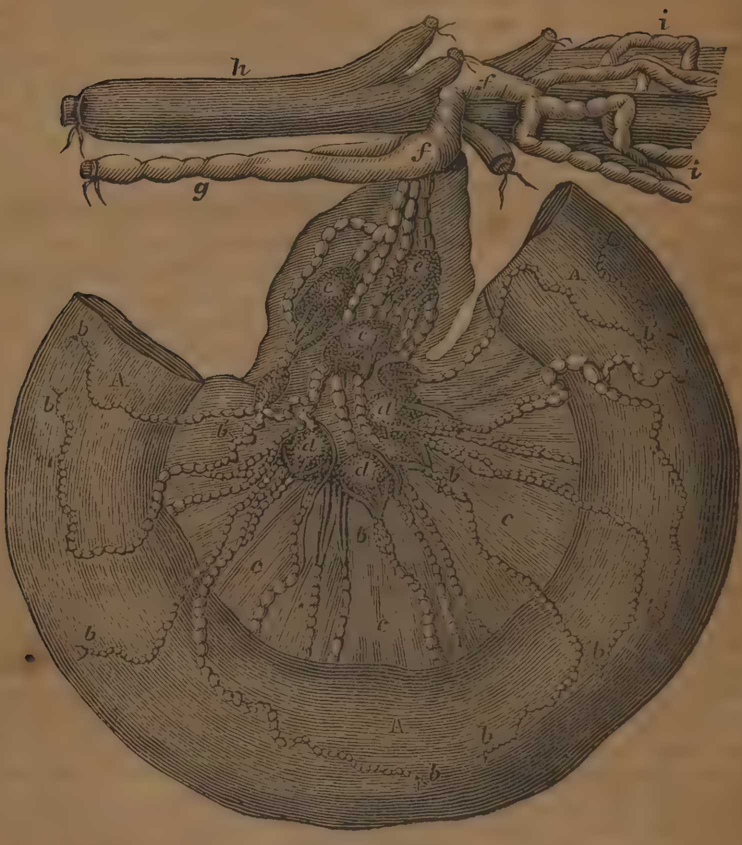
All these are mere speculations, too often entirely gratuitous; and it must be admitted, that we know nothing definite regarding the extreme radicles of the chyliferous vessels. When they become perceptible to the eye, they are observed, as in the subjoined figure, communicating frequently with each other; and forming a minute net-work, first between the muscular and mucous membranes, and afterwards between the muscular and peritoneal, until they terminate in larger trunks *a*, *a*, *a*, *a*. Fig. 109. When they attain the point, at which the peritoneal coat quits the intestine, they leave it also; and creep for an inch or two in the substance of the mesentery; where they enter a first row of mesenteric glands.

Fig. 109.

Chyliferous vessels.

From these they issue, of a greater size and in less number; proceed still farther along the mesentery; and reach a second row, into which they likewise enter. From these, again, they issue, larger and less numerous, anastomosing with others; and proceeding towards the lumbar portion of the spine, where they terminate in a common reservoir,—the *reservoir* of Pecquet, the *receptaculum*

Fig. 110.



Chyliferous Apparatus.

A A. A portion of the jejunum.—*b, b, b, b.* Superficial lacteals.—*c, c, c.* Mesentery.—*d. d, d.*—First row of mesenteric glands.—*e, e, e.* Second row.—*f. f.* Receptaculum chyli.—*g.* Thoracic duct.—*h.* Aorta.—*i, i.* Lymphatics.

or *cisterna chyli*,—which is the commencement of the thoracic duct. This reservoir is situated about the third lumbar vertebra; behind the right pillar of the diaphragm, and the right renal vessels. The chyliferous vessels generally follow the course of the arteries; but sometimes proceed in the spaces between them. They exist in the lower part of the duodenum, through the whole of the jejunum, and in the upper part of the ileum.

M. Voisin affirms, that all, or at least the major part, of the chyliferous vessels pass through the substance of the liver, before they empty their contents into the thoracic duct. After proceeding a certain

distance, they anastomose, he says, with each other, enlarge in size, and are collected together so as to form a kind of plexus below the lobe of Spigelius, towards which they converge. From this point, they penetrate the substance of the liver, through which they ramify, with great minuteness, and finally empty themselves into the receptaculum chyli. To prove, that the chyliferous vessels do pass through the liver, in their course to the thoracic duct, he put a ligature around the duct below the diaphragm, in a dog which had eaten largely, and when digestion was in full activity. The chyliferous vessels were observed to swell, and their whitish colour was distinctly perceived. They could, under these circumstances, be traced without much difficulty, from the interior of the intestinal canal, through the mesenteric glands, as far as their entrance into the liver.

They are composed of two coats; the outer of a fibrous and firm character; the inner very thin, and generally considered to form, by its duplicatures, what are called *valves.* These valves are of a semilunar form, arranged in pairs, and with the convex side turned towards the intestine. Their arrangement has appeared to be well adapted for permitting the chyle to flow from the intestine to the thoracic duct, and for preventing its retrograde course; but Magendie affirms, that their existence is by no means constant. These reputed valves, are considered by Mojon, to be true sphincters. By placing the lymphatic vessels on a glass plate, and opening them through their entire length, he observed by the microscope, that the sphincters are formed by circular fibres, which, by diminishing the size of the vessel at different points, give rise to the nodosities observed at its exterior. If the ends of a varicose lymphatic be drawn in a contrary direction, these nodosities disappear, as well as the suppositious valves. Mojon observed, moreover, that the fibrous membrane of the lymphatics has longitudinal, as well as oblique filaments passing from one contraction to another. These longitudinal fibres have their two extremities attached to the transverse fibres, which, according to him, constitute the sphincters or contractors of the lymphatics. He explains the difficulty often experienced in attempting to inject the lymphatic vessels in a direction contrary to the course of the lymph, by the circumstance, that the little pouches, formed by the sphincters, and the relaxation or distension of their parietes, on filling them with the injected matter, diminish the calibre of the tube, and may even close it entirely.

Some anatomists describe an external coat, which is formed of condensed cellular tissue, and unites the chyliferous vessels to the neighbouring parts.

The *mesenteric glands* or *ganglions* are small, irregularly lenticular, organs; varying in size from the sixth of an inch, to an inch; nearly one hundred in number, and situated between the two laminæ of the mesentery. In them, the lymphatic vessels of the abdomen

terminate, and the chyliferous vessels traverse them, in their course from the small intestine to the thoracic duct. Their substance is of a pale rosy colour; and their consistence moderate. By pressure, a transparent and inodorous fluid can be forced from them; which has never been examined chemically. Anatomists differ with regard to their structure. According to some, they consist of a pellet of chyliferous vessels; folded a thousand times upon each other; subdividing and anastomosing almost *ad infinitum;* united by a cellular tissue, and receiving a number of blood-vessels. In the opinion of others, again, cells exist in their interior, into which the *afferent* chyliferous vessels open; and whence the *efferent* set out. These are filled with a milky fluid, carried thither by the lacteals or exhaled by the blood-vessels.

Notwithstanding the labours of Nuck, Hewson, Abernethy, Mascagni, Cruikshank, Haller, Béclard, and other distinguished anatomists, the texture of these, as well as of the lymphatic glands or ganglions in general, is not demonstrated. All that we know is, that the chyliferous and sanguineous vessels become extremely minute in their substance; and that the communication between the afferent and efferent vessels, through them, is very easy; as mercurial injections pass readily from the one to the other.

The *thoracic duct*, *g*, Fig. 110, is formed by the junction of the chyliferous trunks with the lymphatic trunks from the lower extremity. The *receptaculum chyli*, already described, forms its commencement. After getting from under the diaphragm, the duct proceeds, in company with the aorta, along the right side of the spine, until it reaches the fifth dorsal vertebra; where it crosses over to the left side of the spine, behind the œsophagus. It then ascends behind the left carotid artery; runs up to the interstice between the first and second vertebræ of the chest; where, after receiving the lymphatics, which come from the left arm and left side of the head and neck, it suddenly turns downwards, and terminates at the angle, formed by the meeting of the subclavian and internal jugular veins of the left side.

To observe the chyliferous apparatus to the greatest advantage, it should be examined in an individual recently executed, or killed suddenly, two or three hours after having eaten; or in an animal, destroyed for the purpose of experiment, under the same circumstances. The lacteals are then filled with chyle, and may be readily recognized, especially if the thoracic duct has been previously tied.

The chyliferous vessels were unknown to the ancients. The honour of their discovery is due to Gaspard Aselli, of Cremona, who, in 1622, at the solicitation of some friends, undertook the dissection of a living dog, which had just eaten, in order to demonstrate the recurrent nerves. On opening the abdomen, he perceived a multitude of white, very delicate filaments, crossing the mesentery in all directions. At first, he took them to be nerves; but having

accidentally cut one, he saw a considerable quantity of a white liquor exude, analogous to cream. Aselli also noticed the valves, but he fell into an important error regarding the destination of the vessels;—making them collect in the pancreas, and from thence proceed to the liver.

In 1628, the human lacteals were discovered. Gassendi had no sooner heard of the discovery of Aselli, than he spoke of it to his friend Nicholas-Claude-Fabrice de Peiresc, senator of Aix; who seems to have been a most zealous propagator of scientific knowledge. He immediately bought several copies of the work of Aselli, which had only appeared the year previously, and distributed them amongst his friends of the profession. Many experiments were made upon animals, but the great desire of De Peiresc was, that they should be found in the human body. Through his interest, a malefactor, condemned to death, was given up, a short time before his execution, to the anatomists of Aix; who made him eat copiously; and, an hour and a half after execution, opened the body, in which, to the great satisfaction of De Peiresc, the vessels of Aselli were perceived, in the clearest manner. Afterwards, in 1634, John Wesling gave the first graphic representation of the chyliferous vessels of the human body; and he subsequently indicated, more clearly than his predecessors, the thoracic duct and the lymphatics. Prior to the discovery of the chyliferous and lymphatic vessels, the veins, which arise in immense numbers from the intestines, and, by their union with other veins, form the vena porta, were esteemed the agents of absorption; and, even at the present day, they are considered, by some physiologists, to participate with the chyliferous vessels in the function:—with what propriety we shall inquire hereafter.

The chyle, as it circulates in the chyliferous vessels, has only been submitted to examination in comparatively recent times. The best mode of obtaining it is to feed an animal, and, when digestion is in full progress, to strangle it, or divide the spinal marrow behind the occiput. The thorax must then be opened, through its whole length; and a ligature be passed round the aorta, œsophagus, and thoracic duct, as near the neck as possible. If the ribs of the left side be now turned back or broken, the thoracic duct is observed, lying against the œsophagus. By detaching the upper part, and cutting into it, the chyle flows out. In this way, a small quantity only is obtained; but, if the intestinal canal and chyliferous vessels be repeatedly pressed upon, the flow may be sometimes kept up for a quarter of an hour. It is obviously impossible, in this way, to obtain the chyle pure; inasmuch as the lymphatics, from various parts of the body, are constantly pouring their fluid into the thoracic duct.

From the concurrent testimony of various experimenters, the chyle is a liquid of a milky-white appearance; limpid and transparent in herbivorous animals, but opaque in the carnivorous; neither

viscid nor glutinous to the touch; of a consistence, varying somewhat according to the nature of the food; of a spermatic smell; sweet taste, not dependent on that of the food; neither acid nor alkaline; and of a specific gravity, greater than that of distilled water, but less than that of the blood. Magendie, and Tiedemann, and Gmelin, however, state it to possess a saline taste; to be clammy on the tongue; and sensibly alkaline.

The chymical character of the chyle has been examined by Emmert, Vauquelin, Marcet, and Prout; and is found to resemble that of the blood greatly. In a few minutes after its removal from the thoracic duct, it becomes solid; and, after a time, separates, like the blood, into two parts, a coagulum and a liquid. The coagulum is an opaque white substance; of a slightly pink hue; insoluble in water; but readily soluble in the alkalies, and alkaline carbonates. Vauquelin regards it as fibrine in an imperfect state, or as intermediate between that principle and albumen; but Brande thinks it more closely allied to the caseous matter of milk than to fibrine.

The analyses of Marcet and Prout agree, for the most part, with that of Vauquelin. Dr. Prout has detailed the changes, which the chyle experiences in its passage along the chyliferous apparatus. In each successive stage, its resemblance to the blood was found to be increased.

Another point of analogy with the blood is the fact,—observed by Bauer, and subsequently by Prévost and Dumas,—that the chyle, when examined by the microscope, contains the same globules as the blood; differing from the latter only in their being but half the size, and devoid of the envelope of colouring matter. Although the chyle has essentially the same constituents, whatever may be the food taken, and separates equally into the clot and the serous portion, the character of the aliment may have an effect upon the portion of those constituents and thus exert an influence on its composition. That it scarcely ever contains adventitious substances we shall see hereafter; but it is obvious, that if an animal be fed on diet contrary to its nature, the due proportion of *perfect* chyle may not be formed; and that, in the same way, different alimentary articles may be very differently adapted for its formation. Leuret and Lassaigne, indeed, affirm that in their experiments they found the chyle to differ more according to the nature of the food than to the animal species; but that, contrary to their expectation, the quantity of fibrine, existing in the chyle, bore no relation to the more or less azoted character of the food. They assign it, as constituents, fibrine, albumen, fatty matter, soda, chloruret of sodium and phosphate of lime.

The chief object of Marcet's experiments was to compare the chyle from vegetable, with that from animal food, in the same animal.

The experiments, made on dogs, led him to the following results.

The specific gravity of the serous portion of the chyle is from 1.012 to 1.021, whether it be formed from animal or vegetable diet. Vegetable chyle, when subjected to analysis, furnishes three times more carbon than animal chyle. The latter is highly disposed to become putrid; and this change generally commences in three or four days; whilst vegetable chyle may be kept for several weeks, and even for months, without becoming putrid.* Putrefaction attacks rather the coagulum of the chyle than its serous portion.

The chyle from animal food is always milky; and, if kept at rest, an unctuous matter separates from it, similar to cream, which swims on the surface. The coagulum is opaque, and has a rosy tint. On the other hand, the chyle from vegetable food is almost always transparent, or nearly so, like ordinary serum. Its coagulum is almost colourless, and resembles an oyster; and its surface is not covered with the substance analogous to cream.

Magendie, too, remarks, that the proportion of the three substances, into which the chyle separates, when left at rest;—namely, the fatty substance on the surface, the clot and the serum, varies greatly, according to the nature of the food; that the chyle, proceeding from sugar, for example, has very little fibrine; whilst that from flesh has more; and that the fatty matter is extremely abundant when the food contains fat or oil; whilst scarcely any is found if the food contains no oleaginous matter.

Lastly,—the attention of Prout has been directed to the same comparison. He found, on the whole, less difference between the two kinds of chyle than had been noticed by Marcet. In his experiments, the serum of chyle was rendered turbid by heat, and a few flakes of albumen were deposited; but, when boiled, after admixture with acetic acid, a copious precipitation ensued. To this substance, which thus differs slightly from albumen, Dr. Prout gave the inexpressive name of *incipient albumen.* The following is a comparative analysis, by him, of the chyle of two dogs, one of which was fed on animal, and the other on vegetable substances.

	Vegetable Food.	*Animal Food.*
Water - - - - -	93.6	89.2
Fibrine - - - - -	0.6	0.8
Incipient albumen - - -	4.6	4.7
Albumen, with a little red colouring matter - - - - - -	0.4	4.6
Sugar of milk - - - -	a trace	
Oily matter - - - -	a trace	a trace
Saline matters - - - -	0.8	0.7
	100.0	100.0

* Thénard has properly remarked, that the difference, in the time of putrefaction of these two substances, appears very extraordinary. It is, indeed, inexplicable.

The difference, between the chyle from food of such opposite character, as indicated by these experiments, is insignificant, and indicative of the great uniformity in the action of the agents of this absorption.

With regard to the precise quantity of chyle, that may be formed after a meal, we know nothing definite. When digestion is not going on, there can of course be none formed except from the digestion of the secretions from the digestive tube itself; and, after an abstinence of twenty-four hours, the contents of the thoracic duct will be chiefly lymph. During digestion, the quantity of chyle formed will bear some relation to the quantity of food taken, the nutritive qualities of such food, and the digestive powers of the individual. Magendie, from an experiment made on a dog, estimated, that at least half an ounce of chyle was conveyed into the mass of blood, in that animal, in five minutes; and the flow was kept up, but much more slowly, as long as the formation of chyle continued.

Physiology of Chylosis.

The facts just referred to,—regarding the anatomical arrangement of the chyliferous radicles and mesenteric glands,—will sufficiently account for the obscurity of our views on many points of chylosis.

The impracticability of detecting the mouths or extremities of the chyliferous radicles has been the source of different hypotheses; and, according as the view of open mouths or of the spongy gelatinous tissue has been embraced, the chyle has been supposed to enter immediately into the vessels, or to be received through the medium of this tissue; or, again, to pass through the parietes of the vessels by imbibition.

Let it be borne in mind, however, that not only the action of absorption, but the vessels themselves, are seen only by the "mind's eye;" and that the chyle does not seem to exist anywhere but in the chyliferous vessels. In the small intestine, we see a chymous mass, possessing all the properties we have described, but containing nothing resembling true chyle; whilst, in the smallest lacteal we can detect, it always possesses the same essential properties. Between this imperceptible portion of the vessel, then, and its commencement,—including the latter,—the elaboration must have been effected. Leuret and Lassaigne, indeed, affirm, that they have detected chyle in the chymous mass within the intestine, by the aid of the microscope. They state that globules appeared in it similar to those that are contained in the chyle, and that their dissemination amongst so many foreign matters alone prevents their union in perceptible fibrils. These globules they regard as true chyle,—for the reason, that they observed similar globules in the artificial digestions they attempted; and, on the other hand, never detected them in the digestive secretions. In their view, consequently, chyliferous

absorption would be confined to the separation of the chyle, ready formed in the intestine, from the excrementitious matters united with it. We have already more than once referred to the caution, which it is necessary to adopt, regarding minute microscopic researches; and to the difference, presented to the observer by glasses of different magnifying powers. We must have stronger evidence than this to set aside the overwhelming testimony in favour of an action of selection and elaboration by the absorbents of all organized bodies—vegetable as well as animal. The nutriment of the vegetable may exist in the soil and the air around it; but it is subjected to a vital agency the moment it is laid hold of, and is decomposed to be again united, so as to form the sap. How else can we understand the conversion of the animal matters in the manure into the substance of the vegetable? A like action is doubtless exerted by the chyliferous radicles; and hence all the modes of explaining this part of the function, under the supposition of their being passive, mechanical tubes, are inadequate and unphilosophical. Boerhaave affirmed, that the peristaltic motion of the intestines has a considerable influence in forcing the chyle into the mouths of the vessels; whilst Dr. Young is disposed to ascribe the whole effect to capillary attraction; and he cites the lachrymal duct as an analogous case, the contents of which, he conceives,—and we think with propriety,—are entirely propelled by capillary attraction.

The objections to these views, as regards the chyliferous vessels, are sufficiently obvious. The chyle must, according to them, exist in the intestines; and, if the view of Boerhaave were correct, we ought to be able to obtain it from the chyme by pressure. As the chyle is not present, ready formed, in the intestine, the explanations by imbibition and by capillary attraction are equally inadmissible. There is no analogy between the cases of the lachrymal duct and the chyliferous vessels. In another part of this work, we have affirmed, that the passage of the tears, through the puncta lachrymalia, and along the lachrymal ducts, is one of the few cases in which capillary attraction can, with propriety, be invoked, for the explanation of functions executed by the human frame. In that case there is no conversion of the fluid. It is the same on the conjunctiva as in the lachrymal duct, but, in the case of the chyliferous vessel, a new fluid is formed; there must, therefore, have been an action of selection exerted; and this very action would be the means of the entrance of the new fluid into the mouths of the lacteals. If, therefore, we admit, in any manner, the doctrine of capillary tubes, it can only be, when taken in conjunction with that of the elaborating agency.

"As far as we are able to judge," says Bostock, "when particles, possessed of the same physical properties, are presented to their mouths (the lacteals,) some are taken up, while others are rejected; and if this be the case, we must conceive, in the first place, that a specific attraction exists between the vessel and the particles, and

that a certain vital action must, at the same time, be exercised by the vessel connected with, or depending upon, its contractile power, which may enable the particles to be received within the vessel, after they have been directed towards it. This contractile power may be presumed to consist in an alternation of contraction and relaxation, such as is supposed to belong to all vessels that are intended for the propulsion of fluids, and which the absorbents would seem to possess in an eminent degree." This is all specious: but it is not the less hypothetical.

By other physiologists, absorption is presumed to be effected, by virtue of the peculiar *sensibility* or *insensible organic contractility* or *irritability* of the mouths of the absorbents; but these terms, as Magendie has remarked, are the mere expression of our ignorance, regarding the nature of the phenomenon. The separation of the chyle is, doubtless, a chemical process; seeing that there must be both an action of decomposition and of recomposition; but it is not regulated, apparently, by the same laws, as those that govern inorganic chymistry.

It has already been said, that the chyle always possesses the same essential properties; that it may vary slightly according to the food, and the digestive powers of the individual, but that it rarely if ever contains any adventitious substance,—the function of the chyliferous vessels being restricted to the formation of chyle. The facts and arguments, in favour of this view of the subject, will be given hereafter.

The course of the chyle is, as we have described, along the chyliferous vessels, and through the mesenteric glands into the receptaculum chyli or commencement of the thoracic duct; along which it passes into the subclavian vein.

The chief causes of its progression, are,—first of all, the inappreciable action, by which the chyliferous vessels form and receive the chyle into them. This formation being continuous, the fresh portions must propel those already in the vessels towards the mesenteric glands. It is probable, too, that the vessels themselves are contractile: such was the opinion of Sheldon, Schneider and Cruikshank. Mojon considers, that when the longitudinal fibres, which he has observed in the lymphatics, contract, they draw one sphincter nearer to another, whilst the oblique fibres diminish the diameter. All these fibres, taking their *point d'appui* in the circular fibres, dilate the superior sphincters by drawing the circumference downwards. By this method, the fluid, which enters a lymphatic, irritates the vessel, which contracts upon itself, diminishes its cavity, and sends on the fluid through the open sphincter. A kind of peristaltic action, he conceives, exists in the lymphatics similar to that of the intestines, which may be observed very distinctly, he says, in the lacteal vessels of the mesentery of animals, if opened two or three hours after they have been well fed. Moreover, that the lacteals and lymphatics are possessed of a power of contraction is corro-

borated by the following reasons. *First.* They are small; and tonic contractions are generally admitted in all the capillary vessels. *Secondly.* The ganglions or glands, which cut them at intervals, would destroy the impulse given by the first action of the radicles; and hence require some contraction in the vessels to transport the chyle from one row of these ganglions to another. *Thirdly.* If a chyliferous vessel be opened in a living animal, the chyle spirts out, which could not be effected simply by the absorbent action of the chyliferous radicles; and, *fourthly:* in a state of abstinence, these vessels are found empty; proving, that notwithstanding there has been an interruption to the action of chylous absorption, the whole of the chyle has been propelled into the receptaculum chyli. It is obvious, however, that most of these reasons would apply equally to the elasticity as to the muscularity of the outer coat of these vessels.

A more forcible argument is derived from an experiment by Lauth. He killed a dog, towards the termination of digestion; and immediately opened its abdomen, when he found the intestines marbled, and the chyliferous vessels filled with chyle. Under the stimulation of the air, these vessels began to contract, and, in a few minutes, were no longer perceptible. The result he found to be the same, wherever the dissection was made within twenty-four hours after death; but, at the end of this time, the irritability of the chyliferous vessels was extinct; and they remained distended with chyle, notwithstanding the admission of air. These experiments lead to a deduction which seems, in the absence of less direct proof, scarcely doubtful;—that the chyliferous vessels possess a contractile action, by the aid of which the chyle is propelled along the vessels.

In addition to these propelling causes, the pulsation of the arteries in the neighbourhood of the chyliferous vessels; and the pressure of the abdominal muscles in respiration have been invoked. The former has probably less effect than the latter. It is not, indeed, easy to see how the former can be possessed of any. Of the agency of the latter we have experimental evidence. If the thoracic duct be exposed in the neck of a living animal and the course of the chyle be observed, it will be found accelerated at the time of inspiration, when the depressed diaphragm forces down the viscera; or when the abdomen of the animal is compressed by the hands. We shall find, too, hereafter, that the mode in which the thoracic duct opens into the subclavian exerts considerable effect on the progress of the chyle in its vessels.

We have reason to believe, that the course of the chyle is slow. It has been already stated, that in an experiment on a dog, which had eaten animal food at discretion, Magendie found half an ounce of chyle discharged from an opening in the thoracic duct in five minutes. Still, as he judiciously remarks, the velocity will be partly dependent upon the quantity of chyle formed. If much enters the

thoracic duct, it will probably proceed faster than under opposite circumstances.

In the commencement of the thoracic duct the chyle becomes mixed with lymph. Under the head of lymphatic absorption we shall show how they proceed together into the subclavian, and the effect produced by the circumstances under which the thoracic duct opens into that venous trunk.

It has been a subject of inquiry,—and unfortunately a fruitless one with physiologists,—whether the chyle varies materially in different parts of its course, and what is the precise modification, impressed upon it by the action of the mesenteric glands. The experiments of Reuss, Emmert, and others, seem to show, that when taken from the intestinal side of the mesenteric glands, it is of a yellowish-white colour, does not become red on being exposed to the air, and coagulates but imperfectly, depositing only a small, yellowish pellicle; whilst that, obtained from the other side of the glands and near the thoracic duct, is of a reddish colour, coagulates entirely, and deposits a clot of a scarlet-red colour. Vauquelin, too, affirms, that it acquires a rosy tint as it advances in the apparatus; and that the fibrine becomes gradually more abundant.

These circumstances have given rise to the belief, that the chyle, as it proceeds, becomes more and more animalized, or transformed into the nature of the being to be nourished. This effect has generally been ascribed to the mesenteric glands; and it has been presumed by some to be produced by the exhalation of a fluid into their cells, from the numerous blood-vessels, with which they are furnished. Others, again, consider, that the veins of the glands remove from the chyle everything that is noxious, or purify it. From the circumstance, that the rosy colour of the chyle is more marked on the thoracic, than on the intestinal side of the glands; that the fluid is richer in fibrine after having passed through those glands; and that the rosy colour and fibrine are less, when the animal has taken a larger proportion of food, MM. Tiedemann and Gmelin infer, that it is to the action of the glands, that the chyle owes those important changes in its nature;—the fluid, in its passage through them, obtaining, from the blood circulating in them, the new elements, which animalize it.

These are the chief views, that have been entertained, regarding the use of the mesenteric glands. They are equally gratuitous with the notion, indulged by some, that they act as so many hearts, for the propulsion of the chyle towards the subclavian vein. We are, in truth, totally ignorant of their uses.

In another place, the various hypotheses, that have been indulged, regarding the spleen, will be noticed. It is proper, however, to refer to one, that has been recently proposed by MM. Tiedemann and Gmelin, but which appears little less solid than its precursors. They consider the organ as a dependent ganglion of the absorbent

system, which prepares a fluid, destined to be mixed with the chyle to effect its animalization. They assert that the chyle hardly coagulates, if at all, before it has passed through the mesenteric glands; but after this, the fibrine begins to appear, and is much more abundant after the addition of the lymph from the spleen, which contains a very large quantity of fibrine. Before passing the mesenteric glands, the chyle contains no red particles; but it does so immediately afterwards, and more particularly after it is mixed with the lymph from the spleen, which abounds with them, as with fibrine.

M. Voisin, who, as we have seen, considers that the chyliferous vessels ramify in the substance of the liver, thinks, that by the action of the liver, a species of purification is produced in the chyle, by which the latter is better fitted to mingle with and form part of the blood.

Prior to the discovery of the chyliferous vessels, the mesenteric veins were regarded as the agents of chylous absorption; and as these veins terminate in the vena porta, which is distributed to the liver, this last organ was considered the first organ of sanguification; and as impressing upon the chyle a first elaboration. In this view, the great size of the organ, compared with the small quantity of bile it furnishes, and the exception, which the mesenteric veins and vena porta present to the rest of the venous system, were accounted for, as well as the large size of the liver in the fœtus, although not effecting any biliary secretion; and the fact of its receiving immediately the nutritive fluid from the placenta.

This idea of the agency of the mesenteric veins is now nearly exploded, but not altogether so. There are yet physiologists, and of no little eminence, who regard them as participators in the function of chylosis with the chyliferous vessels themselves. Some of the arguments, used by those gentlemen, are:—*First.* That the mesenteric veins form as much an integrant part of the villi of the intestine as the chyliferous vessels; and, that they have, also, free orifices in the cavity of the intestine. Lieberkühn by throwing an injection into the vena porta, observed the fluid ooze out at the villi of the intestine; and Ribes obtained the same result by injecting spirit of turpentine coloured black. It is manifest, however, that these experiments are insufficient to establish the fact of open mouths. Situated, as those vessels are, in an extremely loose tissue, which affords them but little support, the slightest injecting force might be expected to be sufficient to rupture their sides. *Secondly.* That chyle has often been found in the mesenteric veins. Swammerdam asserts, that, having placed a ligature round the mesenteric veins of a living animal, whilst digestion was going on, he saw whitish, chylous striæ in the blood of those veins; and Tiedemann and Gmelin assert, that they have often, in their experiments, observed the same appearance. If the fact of the indentity

of these striæ with chyle were well established, we should have to bend to the weight of evidence. This is not, however, the case. These gentlemen afford us no other reason for the belief, than the colour of the striæ. The arguments against the mesenteric veins having the power of forming chyle we think irresistible. A separate apparatus exists, manifestly for this purpose, which scarcely ever contains anything but chyle; and, consequently, it would seem unnecessary, that the mesenteric veins should participate in it, especially as the fluid, which circulates in them, is most heterogeneous; and, as we shall see, a compound of various adventitious and other absorptions. Granting, however, that these striæ are truly chyle, it would, it is affirmed, by no means, follow absolutely, that it should be formed by the mesenteric veins. It is possible, that a communication may exist between the chyliferous vessels and these veins. Valæus asserts, that having placed a ligature on the lymphatic trunks of the intestine, chyle passed into the vena portæ. Rosen, Meckel, and Lobstein, affirm that by the use of injections they also detected this inosculation. Lippi states, that the chyliferous vessels have numerous anastomoses with the veins, not only in their course along the mesentery before they enter the mesenteric glands; but also in the glands themselves. Tiedemann and Gmelin concur in the existence of this last anastomosis. Lastly, Leuret and Lassaigne found that a ligature applied round the vena portæ occasioned the reflux of blood into the thoracic duct. *Thirdly.* That the ligature of the thoracic duct has not always induced death, or has not induced it speedily; and, consequently, that the thoracic duct is not the only route, by which the chyle can pass to be inservient to nutrition. In an experiment of this kind by Duverney, the dog did not die for fifteen days. Flandrin repeated it on twelve horses, which appeared to eat as usual, and to keep their flesh. On killing them and opening them a fortnight afterwards, he satisfied himself, that the thoracic duct was not double. Sir Astley Cooper likewise performed the experiment on several dogs, and he found that the majority lived longer than a fortnight, and that none died in the two first days; although, on dissection, the duct was found ruptured and the chyle effused into the abdomen. The experiments of Dupuytren have satisfactorily accounted for these different results. He tied the thoracic duct in several horses. Some died in five or six days, whilst others continued apparently in perfect health. In those, that died in consequence of the ligature, it was impossible to send any injection from the lower part of the duct into the subclavian vein. It was, therefore, presumable, that the chyle had ceased to be poured into the blood, immediately after the duct was tied. On the other hand, in those, that remained apparently unaffected, it was always easy to send mercurial or other injections from the abdominal portion of the duct into the subclavian. The injections followed the duct until near the ligature; when they turned off, entering into large lymphatic vessels, which opened into the subcla-

vian vein, so that, in these cases, the ligature of the thoracic duct had not prevented the chyle from passing into the venous system; and, thus, we can understand why the animals should not have perished.

From every consideration, then, it appears that the chyliferous vessels are the sole organs concerned in chylosis; and we shall see presently, that they refuse the admission of other substances, which must, consequently, reach the circulation through a different channel.

II. ABSORPTION OF DRINKS.

It has been stated, that a wide distinction exists between the gastric and intestinal operations, which are necessary in the case of solid food and liquids. Whilst the former is converted into chyme and passes into the small intestine, to have its chylous part separated from it; the latter, according to their constitution, may either be wholly absorbed or be divided into two portions—if they consist of animal or vegetable infusions—the animal or vegetable substance being subjected to chymification, whilst the watery portion, with its saline accompaniments,—if any such exist,—is absorbed from the stomach or small intestine.

The chyliferous vessels, we have seen, are the agents and the exclusive agents of the absorption of the chyle or nutritive product from the digestion of solids: what then, are the agents of the absorption of liquids? There are but two sets of vessels, on which we can rest for a moment. These are the lacteals or lymphatics of the digestive tube; and the veins of the same canal. But, it has been seen, the chyliferous vessels refuse the admission into their interior of everything but chyle. It would necessarily follow, then, that the absorption of liquids must be a function of the veins. Such is the conclusion of many distinguished physiologists, and on inferences that are logical.

The view is not, however, universally, or perhaps generally, admitted; some assigning the function exclusively to the lacteals; others sharing it between them and the veins. But let us inquire into the facts and arguments, adduced in support of these different opinions. The advocates for the exclusive agency of the chyliferous system affirm, *First*, That whatever is the vascular system, which effects the absorption of drinks, it must communicate freely with the cavity of the intestine; and that the chyliferous system does this. *Secondly*, That this system of vessels is the agent of chylous absorption:—a presumption, that it is also the agent of the absorption of drinks. *Thirdly*, That every physiologist, who has examined the chyle, has described its consistence to be in an inverse ratio with the quantity of drink taken; and, lastly, that when coloured and odorous substances have been conveyed into the intestine, they have been found in the chyliferous vessels and not in the

mesenteric veins. The experiments, however, adduced in favour of this last position are so few and inadequate, that it is surprising they could have, for a time, so completely overturned the old theory. This effect was greatly aided by the zeal and ability of the Hunters, and of the Wind-mill Street School in general, who were the chief improvers of our knowledge regarding the anatomy of the lymphatic system.

The celebrated John Hunter,—who was one of the first, that positively denied absorption by the veins and admitted that of the lymphatics,—instituted the following ingenious and imposing experiment. He opened the abdomen of a living dog; laid hold of a portion of intestine, and pressed out the matters it contained with the hand. He then injected warm milk into it, which he retained by means of ligatures. The veins, belonging to the portion of intestine, were emptied of their blood by puncturing their trunks; and they were prevented from receiving fresh blood, by the application of ligatures to the corresponding arteries. The intestine was then returned into the cavity of the abdomen; and, in the course of half an hour, was again withdrawn and scrupulously examined; when the veins were found still empty, whilst the chyliferous vessels were full of a white fluid. Hunter subsequently repeated the experiment with odorous and coloured substances, but without ever being able to detect them in the mesenteric veins. It may be remarked, also, that Musgrave, Lister, Blumenbach, Seiler and Ficinus assert, that they have detected substances in the chyle of the thoracic duct, which had been thrown into the intestines of animals. The experiments of Hunter, however, are those, on which the supporters of this view of the question principally rely.

Those physiologists, who believe in absorption of liquids by the mesenteric veins, invoke similar arguments and much more numerous experiments. They affirm, that the mesenteric veins, like the chyliferous vessels, have free orifices in the cavity of the intestine, and form constituent portions of the villi; whilst some of them conceive even this arrangement to be unnecessary, and that the fluids can readily pass through the coats of the vessels;—that if the chyliferous system is manifestly an absorbent apparatus, the same may be said of the venous system;—that if the chyle has appeared to be more fluid after much drink has been taken, Boerhaave affirms, that he has seen the blood of the mesenteric veins more fluid under like circumstances; and, lastly, against the experiments of Hunter, numerous others have been adduced, clearly showing, that liquids, injected into the intestine, have been found in the mesenteric veins, whilst they could not be detected in the chyliferous vessels.

To the first experiment of Hunter it has been objected;—that the art of performing physiological experiments was, in his time, imperfect; and that, in order to deduce any useful inferences from it, we ought to know, whether the animal was fasting at the time it was opened, or whether digestion was going on; that the state of the

lymphatics ought to have been examined at the commencement of the experiment, to see whether they were full of chyle, or empty; as well as the milk, to notice whether any changes had supervened, during its stay in the intestine: lastly, that the reasons should have been assigned for the belief that the lacteals were filled with milk at the end of the experiment, and that it was not rather chyle.

The experiment, moreover, has been repeated several times by Flandrin, and by Magendie,—both of them dexterous experimenters,—yet, in no case, was the milk found in the chyliferous vessels. This first experiment of Hunter cannot, therefore, be looked upon as satisfactory. Some illusion must have occurred,—some source of fallacy,—or, otherwise, a repetition of the experiment should have been attended with like results. We shall find, hereafter, that in another experiment, by that distinguished individual, a source of illusion existed, of which he was unaware, but which was sufficient to account for the appearances he noticed.

The experiments of Hunter, with the odorous and coloured substances, have been likewise repeated by many physiologists; and found to be even less conclusive than that with the milk.

Flandrin, who was professor at the Veterinary School of Alfort, in France, thought that, in horses, he could detect an herbaceous odour, in the blood of the mesenteric veins, but not in the chyle. He gave to a horse a mixture of half a pound of honey, and the same quantity of assafœtida; and, whilst the smell of the latter was distinctly perceptible in the venous blood of the stomach and intestine, no trace of it existed in the arterial blood and chyle. Sir Everard Home having given the tincture of rhubarb to an animal, around whose thoracic duct he had placed a ligature, found the rhubarb in the bile and in the urine.

Magendie gave to dogs, whilst they were digesting, a quantity of alcohol, diluted with water, and solutions of camphor, or other odorous fluids; and, on examining the chyle, half an hour afterwards, he detected none of these substances, whilst the blood in the mesenteric veins manifestly exhaled the odour, and afforded the matters by distillation. He gave to a dog four ounces of a decoction of rhubarb; and, to another, six ounces of a solution of the prussiate of potassa in water. Half an hour afterwards, no trace of these substances was detected in the fluid of the thoracic duct, whilst they were contained in the urine. On another dog, he tied the thoracic duct, and then gave it two ounces of a decoction of nux vomica. Death occurred as speedily as in another dog, in which the thoracic duct was pervious. The result was the same, when the decoction was thrown into the rectum, where no chyliferous vessels exist.

Having tied the pylorus in dogs, and conveyed fluids into their stomachs, absorption took place equally, and with the same results. Lastly, with M. Delille he performed the following experiment on a dog, which had been made to eat a considerable quantity of meat previously, in order that the chyliferous vessels might be easily per-

ceived. An incision was made in the abdominal parietes; and a portion of the small intestine drawn out, on which two ligatures were applied, at a short distance from each other. The lymphatics, which arose from this portion of intestine, were very white, and apparent from the chyle that distended them. Two ligatures were placed around each of these vessels; and the vessels divided between the ligatures. Every precaution was taken, that the portion of intestine, drawn out of the abdomen, should have no connexion with the rest of the body by lymphatic vessels. Five mesenteric arteries and veins communicated with this portion of the intestine. Four of the arteries and as many veins were tied and cut, in the same manner as the lymphatics. The two extremities of the portion of intestine were now divided, and separated entirely from the rest of the small intestine. A portion of small intestine, an inch and a half long, thus remained attached to the body by a mesenteric artery and vein only.

These two vessels were separated from each other by a distance of four fingers' breadth; and the cellular coat was removed to obviate the objection, that lymphatics might still exist in it. Two ounces of a decoction of nux vomica were now injected into this portion of intestine, and a ligature was applied to prevent the exit of the injected liquid. The intestine, surrounded by fine linen, was replaced in the abdomen; and, in six minutes, the effects of the poison were manifested with their ordinary intensity; so that everything occurred as if the intestine had been in its natural condition.

Ségalas performed a similar experiment, leaving the intestine, however, communicating with the rest of the body by chyliferous vessels only. On injecting a solution of half a drachm of the alcoholic extract of nux vomica into the intestine; the poisoning, which, in the experiment of Magendie, took effect in six minutes, had not occurred at the expiration of half an hour; but when one of the veins was untied and the circulation re-established, it supervened immediately.

MM. Tiedemann and Gmelin likewise observed the absorption of different colouring and odorous substances from the intestinal canal to be effected, exclusively, by the veins. Indigo, madder, rhubarb, cochineal, litmus, alkanet, camboge, and verdigris: musk, camphor, alcohol, spirit of turpentine, Dippel's animal oil, assafœdita and garlic, the salts of lead, mercury, iron and baryta, were found in the venous blood, but never in the chyle. The prussiate of potassa and sulphate of potassa were the only substances, which, in their experiments, entered the chyliferous vessels.

Such are the chief facts and considerations, on which the believers in the chyliferous absorption and in the venous absorption of drinks, rest their respective opinions. The strength, we think, is manifestly with the latter. Let it be borne in mind, that no sufficient experiments have been recently made, which encourage the idea, that anything is taken up by the chyliferous vessels except chyle; and that

nearly all are in favour of absorption by the mesenteric veins. An exception to this, as regards the chyliferous vessels, seems to exist in the case of certain salts. The prussiate and the sulphate of potassa were detected in the thoracic duct by MM. Tiedemann and Gmelin; the sulphate of iron and the prussiate of potassa by Messrs. Harlan, Lawrence and Coates of Philadelphia; and the last of these salts by Dr. Macneven of New York. "I triturated," says Dr. Macneven "one drachm of crystallized hydrocyanate of potassa with fresh butter and crumbs of bread, which being made into a bolus, the same dog swallowed and retained. Between three and four hours afterwards, Dr. Anderson bled him largely from the jugular vein. A dose of hydrocyanic acid was then administered of which he died without pain, and the abdomen was laid open. The lacteals and thoracic duct were seen well filled with milk-white chyle. On scratching the receptaculum, and pressing down on the duct, nearly half a tea-spoonful of chyle was collected. Into this were let fall a couple of drops of the solution of permuriate of iron, and a deep blue was the immediate consequence."

These very exceptions are strikingly corroborative of the rule. Of the various salts employed these alone appear to have been detected in the chyle of the thoracic duct. It is, therefore, legitimately presumable, that they entered adventitiously, and probably by simple mechanical imbibition;—the mode in which venous absorption seems to be effected.

The property of imbibition, possessed by animal tissues, has already been the subject of remark. It was there shown, that they are not all equally penetrable: and that different fluids possess different penetrative powers. This view is confirmed by the experiments of Tiedemann and Gmelin on the subject engaging us. Although various substances were placed in the same part of the intestinal canal, they were not all detected in the blood of the same vessels. Indigo and rhubarb, for example, were found in the blood of the vena portæ. Camphor, musk, spirit of wine, spirit of turpentine, oil of Dippel, assafœtida, garlic, not in the blood of the intestines, but in that of the spleen and mesentery; the prussiates of iron, lead and potassa in that of the veins of the mesentery; those of potassa, iron and baryta in that of the spleen; the prussiate of potassa and the sulphates of potassa, iron, lead and baryta in the vena portæ as well as in the urine; whilst madder and camboge appear to have been found in the latter fluid only.

The evidence, in favour the action of the chyliferous vessels being restricted to the absorption of chyle, whilst the intestinal veins take up other matters, is not, however, considered by some to be as decisive as it is by us. Adelon, for example, concludes, that as the sectators, on both sides, employ absolutely the same arguments, we are compelled to admit, that the two vascular systems are under exactly similar conditions; and that both, consequently, participate

in the function. We have seen, that whatever may be the similarity of the arguments, the facts are certainly not equal.

It is proper, however, to remark, that all analysts, of recent times, have found great difficulty in detecting inorganic matters when mixed with certain of the compounds of organization; and this may account for substances not having been detected in the thoracic duct, even when they have been present there.

With regard to the mode in which the absorption of fluids is effected, a difference of opinion has existed, chiefly as regards the question,—whether any vital elaboration is concerned, as in the case of the chyle, or whether the fluid, when it attains the interior of the vessel, is the same as without. The arguments in favour of these different views will be detailed under the head of venous absorption. We may merely observe, at present, that water,—the chief constituent of all drinks,—is an essential component of every circulating fluid; that we have no positive evidence, that any action of elaboration is exerted upon it; and that the ingenious and satisfactory experiments of Dr. J. K. Mitchell, of Philadelphia, have shown, that it penetrates most, if not all, animal tissues better than any other liquid whatever; and, consequently, passes through them to accumulate in any of its own solutions. It is probably in this way,—that is, by imbibition,—that all venous absorptions are effected.

But, it has been said, if fluids pass so readily through the coats of the veins;—by reason of the extensive mucous surface, with which they come in contact, a large quantity of extraneous and heterogeneous fluid must enter into the abdominal venous system, when we drink freely; and the composition of the blood be consequently modified; and if it should arrive, in this condition, at the heart, the most serious consequences might result. It has, indeed, been affirmed by a distinguished ornament of his profession, in this country, in a more ingenious than forcible argument to support a long-cherished hypothesis, that "it must at least be acknowledged, that no substance, in its active state, does reach the circulation, since it is shown, that a small portion, even of the mildest fluid, as milk or mucilage, oil or pus, cannot be injected into the blood-vessels, without occasioning the most fatal consequences." But the effects are greatly dependent upon the mode in which the injection is made. If a scruple of bile be sent forcibly into the crural vein, the animal will generally perish in a few moments. The same occurs, if a small quantity of atmospheric air be rapidly introduced into the same vessel. The animal, indeed, according to Sir Charles Bell, dies in an instant, when a very little air is blown into the veins;—and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame. In this way, according to Beauchêne, Larrey, Dupuytren, Warren of Boston, Mott and Stevens of New-York, Delpech, Gräfe, Ulrick, Sir Astley Cooper and others, operations

sometimes prove fatal;—the air being drawn in by the divided veins. If, however, the scruple of bile or the same quantity of atmospheric air be injected into one of the branches of the vena portæ, no apparent inconvenience is sustained. Magendie concludes, from this fact, that the bile and atmospheric air, in their passage through the myriads of small vessels, into which the vena portæ divides and subdivides in the substance of the liver, become thoroughly mixed with the blood, and thus arrive at the vital organs in a condition to be unproductive of mischief.

This view is rendered the more probable by the fact, that if the same quantity of bile or of air be injected very slowly into the crural vein, no perceptible inconvenience is sustained. M. Lepelletier affirms, that in the amphitheatre of the *Ecole Pratique* of Paris, in the presence of upwards of two hundred students, he injected thrice into the femoral vein of a dog, of middle size, at a minute's interval, three cubic inches of air, each time, without observing any other effect than struggling, whining, and rapid movements of deglutition, and these symptoms existed only whilst the injection was going on. Since that he has often repeated the experiment with identical results,—"proving," he observes, "that the fatal action of the air is, in this case, mechanical, and that it is possible to prevent the fatal effects by injecting so gradually, that the blood has power to disseminate, and perhaps even to dissolve the gas with sufficient promptitude to prevent its accumulation in the cardiac cavities."

As liquids are frequently passed off by the urinary organs soon after they have been taken, it has been believed by some,—either that there are vessels, which form a direct communication between the stomach and bladder; or that a transudation takes place through the parietes of the stomach and intestine, and that the fluids proceed through the intermediate cellular tissue to the bladder. Both these views, we shall hereafter show to be devoid of foundation.

In those animals, in which the cutis vera is exposed, nutritive absorption is effected through that envelope. In the polypiæ medus, a radiaria, and vermes, absorption is active, and according to Zeder and Rudolphi, those entozoa, that live in the midst of animal humours, imbibe them through the skin. A few years ago, Jacobson instituted experiments on the absorbing power of the helix of the vine, (*Limaçon des vignes*). A solution of prussiate of potassa was poured over the body. This was rapidly absorbed, and entered the mass of blood in such quantity, that the animal acquired a deep blue colour, when sulphate of iron was thrown upon it. In the frog, toad, salamander, &c. the cutaneous absorption is so considerable, that occasionally the weight of water, taken in, in this way, is equal to that of the whole body. We shall see, hereafter, that the nutrition of the fœtus in utero is mainly, perhaps, accomplished by nutritive absorption effected through the cutaneous envelope.

The application of the views of Dutrochet and of Raspail—elsewhere described—to the function of absorption, will be obvious.

The digestive absorption of solids and liquids forms a part only of the *nutritive absorption*, and that which has been termed the *external*. There are also *internal* nutritive absorptions, which require equal consideration. These are the *interstitial* or *decomposing absorption* or *absorption of solids*;—the *absorption of recrementitial secreted fluids*; and the absorption of certain parts of the *excrementitial*.

The first of these, or the absorption of solids, forms a part of the function of nutrition, and will be considered under that head. It is by virtue of this variety of absorption, that the growth of the body is kept within due bounds; and that tumours of various kinds are made to disappear.

The *absorption of recrementitial secretions* keeps those fluids in the proper quantity, which are poured out in various parts of the body, and are inservient to useful purposes. Without a due action on the part of the absorbents, accumulation of those fluids would take place, followed by serious consequences. By this kind of absorption—all the serous fluids, the synovia, the fat, the marrow and medullary fluid; the colouring humours of the iris, uvea, choroid and skin; the humours 'of the eye, the liquor of Cotugno, &c. &c. are taken up in order that fresh particles may be deposited. Some of them, as the fat, may perhaps be regarded as truly nutritive; constituting a provision, to which recourse may be had in time of need.

The last variety,—the *absorption of excrementitial secretions*,—applies only to a part of the secreted fluids. It is effected whilst they are passing over the excretory passages, and consists chiefly perhaps in the absorption of the water they contain, whilst they remain in contact with the absorbents of the canal. To this kind of absorption all the excretory fluids are subjected.

The two first of these absorptions belong to what have been termed *internal absorptions*. They differ from the digestive absorptions, that have engaged our attention, in the circumstance, that the chyliferous vessels cannot, of necessity, be the absorbing agents. The question is, here, between the lymphatics and veins; and, before we consider to which the function must be assigned, it may be well to inquire into the structure of the lymphatics, and into the nature and course of the fluid that circulates within them,—the lymph.

Sect. II. OF THE ABSORPTION OF LYMPH.

This function is effected by agents, which strongly resemble those concerned in the absorption of the chyle. One part of the vascular apparatus is, indeed, common to both,—the *thoracic duct.* We are much less acquainted, however, with the physiology of lymphatic, than of chyliferous, absorption.

Anatomy of the Lymphatic Apparatus.

The lymphatic apparatus consists of lymphatic vessels, lymphatic glands or ganglia, and thoracic duct. The latter, however, does not form the medium of communication between all the lymphatic vessels and the venous system.

1. *Lymphatic vessels.*—These vessels exist in almost all parts of the body; and, when they become visible, they have the shape of cylindrical, transparent, membranous tubes, of small size, and anastomosing freely with each other, so as to present, everywhere, a reticular arrangement. They are extremely numerous; more so, however, in certain parts than in others. They have not yet been found in the brain, spinal marrow, eye, internal ear, &c.; but this is no proof that they do not exist there. It may be merely an evidence that they are so minute as to escape observation.

In their progress towards the venous system, they go on forming fewer and fewer trunks; yet they always remain small. This uniformity in size is peculiar to them. When an artery sends off a branch, its size is sensibly diminished; and when a vein receives a branch, it is enlarged; but when a lymphatic ramifies, there is, generally, little change of size, whether the branch, given off, be large or small.

The lymphatics consist of two planes,—the one *superficial*, the other *deep-seated.* The former creep under the outer covering of the organ, or of the skin, and accompany the subcutaneous veins. The latter are seated more deeply in the interstices of the muscles, or even in the tissue of parts, and accompany the nerves and great vessels. These planes anastomose with each other. This arrangement occurs not only in the limbs, but in the trunk, and in every viscus. In the trunk, the superficial plane is seated beneath the skin; and the deep-seated between the muscles and the serous membrane that lines the splanchnic cavities. In the viscera, one plane occupies the surface, the other appears to arise from the parenchyma.

The two great trunks of the lymphatic system, in which the lymphatic vessels of the various parts of the body terminate, are the thoracic duct, and the great lymphatic trunk of the right side. The course of the thoracic duct has already been described. It is

formed of three great vessels;—one, in which all the lymphatics and lacteals of the intestines terminate; and the other two, formed by the union of the lymphatics of the lower half of the body. Occasionally, the duct consists of several trunks, which unite into one before reaching the subclavian vein; but more frequently it is double. In addition to the lymphatics of the lower half of the body, the thoracic duct receives a great part of those of the thorax, and all those from the left half of the upper part of the body. At its termination in the subclavian, there is a valve, so disposed as to allow the lymph to pass into the blood; and to prevent the reflux of the blood into the duct. We shall see, however, that its mode of termination in the venous system possesses other advantages.

The other trunk is formed by the absorbents from the right side of the head and neck, and from the right arm. It is very short, being little more than an inch, and sometimes not a quarter of an inch, in length, but of a diameter nearly as great as the thoracic duct. A valve also exists at the mouth of this trunk, which has a similar arrangement and office with that of the left side.

The lymphatics have been asserted to be more numerous than the veins; by some, indeed, the proportion has been estimated at fourteen superficial lymphatics to one superficial vein; whence it has been deduced, that the capacity of the lymphatic system is greater than that of the venous. This must, of course, be mere matter of conjecture. The same may be said of the speculations that have been indulged regarding the mode in which the lymphatic radicles arise,—whether by open mouths or by some spongy mediate body. The remarks made, regarding the chylous radicles, apply with equal force to the lymphatic.

It has been a matter of some interest to determine, whether the lymphatic vessels have not other communications with the venous system than by the two trunks just described; or, whether, soon after their origin, they do not open into the neighbouring veins,—an opinion which has been enunciated by many of those who believe in the doctrine of absorption by the lymphatics exclusively, in order to explain why absorbed matters are found in the veins. Many of the older, as well as more modern, anatomists have professed a similar opinion; whilst it has been strenuously combated by Sömmering, Rudolphi, and others.

Vieussens affirmed, that, by means of injections, lymphatic vessels were distinctly seen to originate from the minute arteries, and to terminate in the small veins. Sir William Blizard asserts, that he twice observed lymphatics terminating directly in the iliac veins. Mr. Bracy Clarke found the trunk of the lymphatic system of the horse to have several openings into the lumbar veins. Ribes, by injecting the supra-hepatic veins, saw the substance of the injection enter the superficial lymphatics of the liver. Alard considers the lymphatic and venous systems to communicate at their origins.

Vincent Fohmann, that the lymphatic vessels communicate directly with the veins, not only in the capillaries, but in the interior of the lymphatic glands. Lauth, of Strasbourg,—who went to Heidelberg to learn from Fohmann his plan of injecting,—announced the same facts in 1824.

By this anatomical arrangement, Lauth explains how an injection, sent into the arteries, reaches the lymphatics, without being effused into the cellular tissue; the injection passing from the arteries into the veins, and thence, by a retrograde route, into the lymphatics. Béclard believed, that this communication exists at least in the interior of the lymphatic glands; and he supported his opinion by the fact, that in birds, in which these glands are wanting, and are replaced by plexuses, the lymphatic vessels in these plexuses are distinctly seen to open into the veins. Lastly, in 1825, Regolo Lippi, of Florence, in his *Illustrazioni fiziologiche e patologiche del Sistema Linfatico-chilifero*, has made these communications the express subject of his work. According to him, the most numerous exist between the lymphatic vessels of the abdomen and the vena cava inferior and all its branches. So numerous are they, that every vein receives a lymphatic vessel, and the sum of all those vessels would be sufficient to form several thoracic ducts. Opposite the second and third lumbar vertebræ, these lymphatic vessels are manifestly divided into two orders:—some ascending, and emptying themselves into the thoracic duct; others descending and opening into the renal vessels and pelves of the kidneys. Lippi admits the same arrangement, as regards the chyliferous vessels; and he adopts it to explain the promptitude with which drinks are evacuated by the urine.

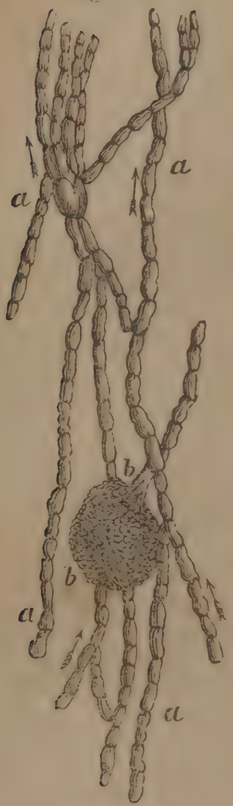
Subsequent researches do not seem to have confirmed the statements of Lippi. G. Rossi, indeed, in Omodei's *Annals* for January, 1826, maintains, that the vessels, which Lippi had taken for lymphatics, were veins. The question is still *sub lite*.

Magendie conceives the most plausible view regarding the lymphatics to be:—that they arise by extremely fine roots in the substance of the membranes and cellular tissue, and in the parenchyma of organs, where they appear continuous with the final arterial ramifications, as it frequently happens, that an injection, sent into an artery, will pass into the lymphatics of the part to which it is distributed.

The structure of the lymphatic vessels is the same as that of the lacteals. They have the same number and character of coats, the same crescentic valves or sphincters, occurring in pairs, and giving them the knotted and irregular appearance, for which they are remarkable;—every contraction indicating the presence of a pair of valves, or sphincter.

In man, each lymphatic, before reaching the venous system, passes

Fig. 111.



Lymphatics.

a, a, a, a. Lymphatic vessels proceeding towards the thoracic duct.—*b, b.* Lymphatic glands. The arrows indicate the direction in which the chyle passes.

through a *lymphatic gland* or *ganglion;* formerly called a *conglobate gland.* These organs are extremely numerous; and in shape, structure, and probably in function, entirely resemble the mesenteric glands. They, therefore, do not demand any distinct notice. They exist more particularly in the axillæ, neck, in the neighbourhood of the lower jaw, beneath the skin of the nape of the neck, in the groins, and in the pelvis—in the neighbourhood of the great vessels. The connexion between the lymphatic vessels and those glands is exactly analogous to that between the chyliferous vessels and the mesenteric glands.

Chaussier includes, in the lymphatic system, certain organs, whose uses in the economy are not manifest,—the thymus gland, the thyroid gland, the supra-renal capsules, and perhaps the spleen. These he considers as varieties of the same species, under the name *glandiform ganglions.*

The *thymus gland* is a body, consisting of distinct lobes, situated at the upper and anterior part of the thorax, behind the sternum. It belongs more particularly to fœtal existence, and will be investigated hereafter.

The *thyroid gland* is, also, a lobular organ, situated at the anterior part of the neck, beneath the skin and some subcutaneous muscles, and resting upon the anterior and inferior part of the larynx, and the first rings of the trachea. It is formed of lobes, which subdivide into lobules and granula; has a red and sometimes a yellow colour; and presents, internally, vesicles, filled with a fluid, which is viscid and colourless or yellowish. It has no excretory duct; and, consequently, it is difficult to discover its use. It is larger in the fœtus than in the adult; and has, therefore, been supposed to be, in some way inservient to fœtal existence. It continues, however, through life, receives large arteries, as well as a number of nerves and lymphatics, and hence, it has been supposed, fills some important office through the whole of existence. This, however, is all conjecture.

The thyroid gland is the seat of *goître*, or *bronchocele*, the *swelled neck*, *Derbyshire neck*, *papas*, &c. as it has been termed in different quarters of the globe,—a singular affection, which is common at

at the base of lofty mountains in all parts of the world; and, in the cure of which, we have a valuable remedy in the iodine. The sorbefacient property of this drug is particularly exerted on the thyroid gland and on the mammæ; and it affords us an additional instance, to the many already known, of remedial agents, not only exerting their properties upon a particular system, but even upon a small part of such system, without our being able, in the slightest degree, to account for the preference. The iodine stimulates the absorbent vessels of the gland to augmented action; and the consequence is, the absorption of the morbid deposit.

Lastly, the *supra-renal* or *atrabiliary capsules* or *glands*, are small bodies in the abdomen, without the peritoneum, and above each kidney. The arteries, distributed to them, are large; and the glands themselves are larger in the fœtus than in the adult. They, likewise, remain during life. These bodies consist of small sacs, with thick parenchymatous parietes: they are lobular and granular; the internal cavity being filled with a viscid fluid, which is reddish in the fœtus, yellow in childhood, and brown in old age.

With their uses we are totally unacquainted. By the ancients, they were believed to be the secretory organs of the imaginary atrabilis; and hence their name.

Lymph may be procured in two ways, either by opening a lymphatic vessel, and collecting the fluid, that issues from it,—but this is an uncertain method,—or by making an animal fast for four or five days, and then obtaining the fluid from the thoracic duct. This has been considered pure lymph; but it is obvious, that it must be mixed with the product of the digestion of the different secretions from the part of the digestive tube above the origin of the chyliferous vessels.

The fluid, thus obtained, is of a rosy, slightly opaline tint; of a marked spermatic smell, and saline taste. At times, it is of a decidedly yellowish colour; and, at others, of a madder red; circumstances which may have given occasion to erroneous inferences, in experiments, made on the absorption of colouring matters. Its specific gravity is, to that of distilled water, as 1022.28 to 1000.00. Its colour is affirmed to be more rosy, in proportion to the length of time the animal has fasted. When examined by the microscope, it exhibits globules like those of the chyle; and, like the chyle, bears considerable analogy, in its chymical composition, to the blood. When left at rest, it separates into two portions;—the one a liquid, nearly like the serum of the blood; and the other a coagulum or clot of a deeper rosy hue; in which is a multitude of reddish filaments, disposed in an arborescent manner; and, in appearance, very analogous to the vessels, which are distributed in the tissue of the organs.

When a portion of coagulated lymph is examined, it seems to consist of two parts;—the one, which is solid, formed of numerous

cells, containing the other or more liquid part; and, if the solid portion be separated, the latter coagulates.

Mr. Brande collected the lymph from the thoracic duct of an animal, which had been kept without food for twenty-four hours. He found its chief constituent to be water; besides which, it contained muriate of soda and albumen;—the latter being in such minute quantity, that it coagulated only by the action of galvanism. The lymph of a dog yielded to Chevreul, water, 926.4; fibrine, 4.2; albumen, 61.0; muriate of soda, 6.1; carbonate of soda, 1.8; phosphate of lime, phosphate of magnesia, and carbonate of lime, 0.5.

It is impossible to estimate the quantity of lymph contained in the body. It would seem, however, that, notwithstanding the great capacity of the lymphatic vessels, there is, under ordinary circumstances, but little fluid circulating in them. Frequently, when examined, they have appeared to be empty, or pervaded by a mere thread of lymph. Magendie endeavoured to obtain the whole of the lymph from a dog of large stature. He could collect but an ounce and a half; and it appeared to him, that the quantity increased, whenever the animal was kept fasting; but on this point he does not seem to express himself positively.

Physiology of Lymphosis.

The term *lymphosis* has been proposed by Chaussier for the action of elaboration, by which lymph is formed; as *chylosis* has been, for the formation of chyle; and *hæmatosis*, for that of the blood. In describing the organs, concerned in this function, the striking similarity, we might almost say, identity, in structure and arrangement between them and the chyliferous organs, will have been apparent. A part, indeed, of the vascular apparatus is common to both; and they manifestly constitute one and the same system. This would be sufficient to induce us to assign them similar functions; and it would require powerful and positive testimony to establish an opposite view. At one period, the lymph was considered to be simply the watery portion of the blood; and the lymphatic vessels were regarded as the mere continuation of the ultimate arterial ramifications. It was affirmed, that the blood, on reaching the final arterial branches, separated into two parts; the red and thicker portion returning to the heart by the veins; and the white, serous portion passing by the lymphatics. The reasons for this belief were, the great resemblance between the lymph and serum of the blood; and the facility with which an injection passes, in the dead body, from the arterial, into the lymphatic capillary vessels. Magendie has revived the ancient doctrine; and, of consequence, no longer considers the lymphatics to form part of the absorbent system; but to belong to the circulatory apparatus, and to serve, as we shall see, the office of waste pipes, in cases of emergency. Without canvassing this subject now, we may assume it

for granted, that the lymph, which circulates in the lymphatic vessels, is identical in its nature, or as little subject to alteration as the chyle; and that, consequently, whatever may be the materials, that constitute it, an action of elaboration and selection must be exerted in its formation.

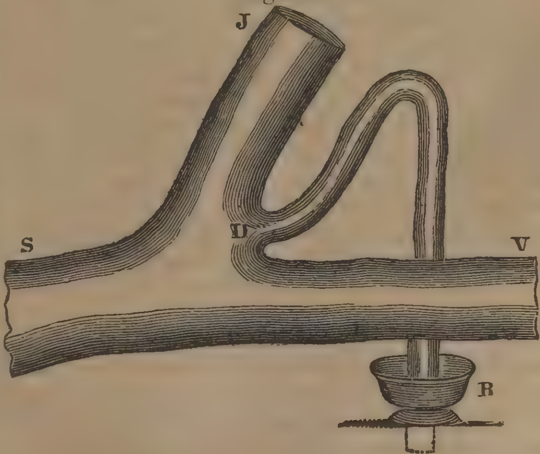
As many of the tissues of the body do not receive red blood: it has been conceived, that they are nourished by the lymph. Dr. S. Jackson is of this opinion: because no other fluid, he thinks, approaches so closely to the blood in its characters, and is consequently so well adapted to vital actions. One office of the lymphatics, in his view, is to restore the lymph back to the circulation,—an office, which he regards as not incompatible with the existence of a function of absorption likewise.

That the lymph strongly resembles the blood is no evidence, however, of its being formed from that fluid: the chyle, which it resembles even more than it does the blood, is procured from materials differing largely from its own nature; more, indeed, than any of the substances, whence the lymph is formed, differ from that fluid.

Assuming, for the present, that the lymph is wholly obtained from materials already deposited in the body; the next inquiry is;—into the mode in which the separation and simultaneous absorption are effected. On this topic, we have no additional arguments to employ to those adduced, regarding the function of the chyliferous radicles. In every respect they are identically situated; and to their history we refer for an exposition of how little we know of this part of lymphosis.

The causes of the progression of the lymph in the vessels are the same as those that influence the chyle. In addition, however, to those mentioned under *chyliferous absorption*, there is one, which applies equally to chyliferous and lymphatic vessels; and arises from the mode, in which the thoracic duct enters the subclavian vein. It has been already observed, that this occurs at the point of junction between the jugular and subclavian, as at

Fig. 112.



D, Fig. 112, where J represents the jugular; and V S, the subclavian, in which the blood flows from V towards S, the cardiac extremity.

Now it is a physical fact, that when a small tube is inserted perpendicularly into the lower side of a horizontal conical pipe, in which the water is flowing from the narrower to the wider portion; and if the small vertical tube be made to dip into a vessel of water, not only will the water of the larger pipe not descend into the vessel; but it will actually draw up the water through the small tube, so as to empty the vessel. Instead of supposing the canals in Fig. 112, to be veins and the thoracic duct; let us presume, that they are rigid mechanical tubes; and that the extremity of the tube D, which represents the thoracic duct, dips into the vessel B. As the fluids, proceeding from J to S and from V to S are passing from the narrower portions of conical tubes to wider, it follows, that the fluid will be drawn out of the vessel B, simply by traction, or, by what Venturi terms, the *lateral communication of fluids.* This would happen in whatever part of the vessel the tube B D terminated. But its insertion at D has another advantage. By the mode in which the current, from J towards S, unites with that from V towards S, a certain degree of diminished pressure must exist at D; so that the atmospheric pressure, on the surface of the water, in the vessel B, will likewise be exerted in propelling it forwards. In the progress of the chyle and lymph, then, along the thoracic duct, not only may the attraction of the more forcible stream along the veins draw the fluid in the thoracic duct along with it, but, owing to the diminished pressure at the mouth of the duct, atmospheric pressure may have some—although probably but little—influence, in forcing the chyle and lymph from the chyliferous and lymphatic radicles onwards. The lymphatic glands have been looked upon as small hearts for the propulsion of the lymph; and Malpighi accounts for the greater number in the groin in this way;—the lymph having to ascend to the thoracic duct against its own gravity; this appears, also, to have been somewhat the opinion of Bichat. There seems, however, to be nothing in their structure, which should lead to this belief; and, if not muscular or contractile, it is manifest, that their number must have the effect of retarding rather than of accelerating the flow of the lymph. The most prevalent sentiment is, that they are somehow concerned in the admixture of the lymph; and by many it is conceived, that some kind of elaboration is effected by them; but, on this topic, we have only conjectures for our guidance. Of their true functions we know nothing definite.

On the subject of the moving powers of the lymph, Adelon has judiciously remarked, that if we admit the lymph to be the serous portion of the blood, and that the lymphatics are vessels of return, as the veins are, the heart might be considered to have the same influence over lymphatic, that it has been presumed to have over

venous, circulation; and it is somewhat singular, that its action has not been invoked by those who embrace that opinion.

Hereafter, however, we shall see, that even in the circulation in the veins the agency of the heart can have little or no influence. Still less can it be expected to exert an influence over a system, so obscurely connected with the arteries as the lymphatic, especially when regard is paid to the numerous ganglions, which must have the effect of destroying such force, if exerted.

In the *Philosophical Transactions* for 1833, Professor Müller, of Bonn, affirms, that he has lately discovered, that the frog, and several other amphibious animals are provided with large receptacles for the lymph, situated immediately under the skin, and exhibiting distinct and regular pulsations, like the heart. The use of these lymphatic hearts appears to be to propel the lymph along the lymphatics. In the frog four of these organs have been found; two posterior situated behind the joint of the hip, and two anterior on each side of the transverse process of the third vertebra, and under the posterior extremity of the scapula. The pulsations of these lymphatic hearts do not correspond with those of the sanguiferous heart; nor do those of the right and left sides take place synchronously. They often alternate in an irregular manner.

The course of the lymph is by no means rapid. If a lymphatic vessel be divided, in a living indivudual, the lymph oozes out slowly, and never with a jet. Cruikshank estimated its velocity along the vessels to be four inches per second or twenty feet per minute; but the data for any such evaluation are altogether inadequate.

In man and in living animals, the lymphatics of the limbs, head, and neck rarely contain lymph; their inner surface appearing to be merely lubricated by a very thin fluid. Occasionally, however, the lymph stops in different parts of the vessels; distends them; and gives them an appearance very like that of varicose veins, except as to colour. Sömmering states, that he has seen several in this condition on the top of the foot of a female; and Magendie one around the corona glandis of the male. In dogs, cats and other living animals, lymphatics, filled with lymph, are frequently seen at the surface of the liver, gall-bladder, vena cava, vena portæ, and at the sides of the spine. Magendie remarks, that he has never met with the thoracic duct empty, even when the lymphatics of the rest of the body were entirely so. It must be recollected, however, that the thoracic duct must always contain the product of the digestion either of food or of the secretions from the alimentary tube. This kind of stagnation of lymph in particular vessels has given occasion to the belief, that the lymph flows with different degrees of velocity in the different parts of the system; and the notion has entered into the pathological views of different writers, who have presumed, that something like determinations of lymph can occur, so as to produce lymphatic swellings. Bordeu, indeed, speaks of *currents*

of lymph. The whole phenomena of the course of the lymph negative such presumption; and induce us to believe, that its progress is pretty uniform and always slow; and when an accumulation or engorgement or stagnation occurs in any particular vessel, it is more probably owing to increased secretion by the lymphatic radicles, which communicate with the vessel in question, and the consequently augmented quantity of lymph.

The lymph, which proceeds by the thoracic duct, is emptied, along with the chyle, into the subclavian vein. At the confluence, a valve is placed, which does not, however, appear to be essential, as the duct opens so favourably between the two currents from the jugular and subclavian, that there is no tendency for the blood to reflow into it. It has been suggested, that its use may be,—to moderate the instillation of the fluid of the thoracic duct into the venous blood. With regard to the question, whether the lymph is the same at the radicles of the lymphatics as in the thoracic duct, or whether it does not gradually become more and more animalized in its course towards the venous system, and especially in its progress through the lymphatic glands, the remarks, made upon the subject, as respects the chyle, apply with equal force to the lymph; and our ignorance is no less profound.

The glands of the mesentery and of the lymphatics in general, seem to be concerned in some of the most serious diseases. Swelling of the lymphatic glands of the groin indicates the existence of a venereal sore on the penis. A wound on the foot will produce tumefaction of the inguinal glands: one on the hand will inflame the glands in the axilla. Whenever, indeed, a lymphatic gland is symptomatically enlarged, the source of irritation will be found at a greater distance from the vein into which the great lymphatic trunks pour their fluid, than the gland is. In plague, one of the essential symptoms is the appearance of swelling of the lymphatic glands of the groin and axilla; hence, it has been termed, by some, *adeno-adynamic fever* (from αδην, a gland.) In scrofula, the lymphatic system is generally deranged; and, in the doctrine of Broussais, a very active sympathy is affirmed to exist between the glands of the mesentery, and the mucous surface of the stomach and intestines. This discovery, we are told, belongs to the "*physiological doctrine*," which has shown, that all gastro-enterites are accompanied by tumefaction of the mesenteric glands: although chyle may be loaded with acrid, irritating or even poisonous matters, it traverses the glands with impunity, provided it does not inflame the gastro-intestinal mucous surface. "Our attention," Broussais adds, "has been for a long time directed to this question, and we have not observed any instance of mesenteric glanglionitis, which had not been preceded by well-evidenced gastro-enteritis." The discovery will not immortalize the "doctrine." We should as naturally look for tumefaction of the mesenteric glands or ganglia,

in cases of irritation of the intestine, as for enlargement of the glands of the groin when the foot is irritated.

Lastly; the lymph, from whatever source obtained—united with the chyle—is discharged into the venous system. Both of these, therefore, go to the composition of the body. They are entirely analogous in properties; but differ materially in quantity;—the nutritious fluid, formed from materials obtained from without, being by far the most copious. A due supply of it is required for continued existence; yet the body can exist for a time, even when the supply of nutriment is entirely cut off. Under such circumstances, the necessary proportion of nutritive fluid must be obtained from the decomposition of the tissues; but, from the perpetual drain, which takes place through the various excretions, this soon becomes insufficient, and death is the result.

We have seen, that both chyle and lymph are poured into the venous blood;—itself a compound of the remains of arterial blood, and of various heterogeneous absorptions. As an additional preliminary to the investigation of the agents of internal absorption, let us now inquire into the nature and course of the fluid contained in the veins; but so far only as to enable us to understand the function of absorption; the other considerations, relating to the blood, appertain to the function of circulation.

Sect. III. VENOUS ABSORPTION.

Anatomy of the Venous System.

This system consists of myriads of vessels, called *veins*, which commence in the very textures of the body, by what are called *capillary vessels;* and from thence pass to the great central organ of the circulation—the *heart;* receiving, in their course, the products of the various absorptions not only affected by themselves, but by the chyliferous and lymphatic vessels.

The origin of the veins, like that of all capillary vessels, is imperceptible. By some, they are regarded as continuous with the capillary arteries; Malpighi and Leeuenhoek state this as the result of their microscopic observations on living animals; and it has been inferred, from the facility with which an injection passes from the arteries into the veins. According to others, cells exist between the arterial and the venous capillaries, in which the former deposit their fluid and whence the latter obtain it. Others, again, substitute a spongy tissue for the cells.

A question has also been asked,—whether the veins terminate by open mouths; or whether there may not be more delicate vessels, communicating with their radicles, similar to the exhalants, which are presumed to exist at the extremities or the arteries, and which are the agents of exhalation.

All this is, however, conjectural. It has already been observed, that the mesenteric veins have been considered to terminate by open mouths in the villi of the intestines; and the same arrangement has been conceived to prevail with regard to other veins. Ribes concludes, from the results of injecting the veins, that some of the venous capillaries are immediately continuous with the minute arteries, whilst others open into the cells of the laminated tissue, and into the substance of the different organs.

Fig. 113.

Ramifications of the splenic artery in the spleen.

When the veins become visible, they appear as an infinite number of tubes, extremely small, and communicating very freely with each other; so as to form a very fine net-work. These vessels gradually become larger and less numerous, but still preserve their

reticular arrangement; until, ultimately, all the veins of the body empty themselves into the heart, by three trunks,—the *vena cava inferior*, the *vena cava superior*, and the *coronary vein*. The *first* of these receives the veins from the lower part of the body, and extends from the fourth lumbar vertebra to the right auricle; the *second* receives all the veins of the upper part of the body; and into it the subclavian opens, into which the chyle and lymph are discharged. It extends from the cartilage of the first rib to the right auricle. The coronary vein belongs to the heart exclusively.

Between the superior and inferior cava a communication is formed by means of the vena azygos.

Certain organs appear almost wholly composed of venous radicles. The spleen is one of these.

The accompanying figure, Fig. 113, represents the ramifications of the splenic artery, *a*, in the substance of that organ; and if we consider, that the splenic vein has corresponding ramifications, the viscus would seem to be almost wholly formed of blood-vessels. The same may be said of the corpus cavernosum of the penis and clitoris, the nipple, urethra, glans penis, &c. If an injection be thrown into one of the veins that issue from these different tissues, they are wholly filled by the injection; which rarely occurs, if the injection be forced into the artery. Magendie affirms, that the communication of the cavernous tissue of the penis with the veins occurs through apertures two or three millimeters—In. 0.117—in diameter.

In their course towards the heart, particularly in the extremities, the veins are divided into two planes;—one subcutaneous or superficial; the other deep-seated, and accompanying the deep-seated arteries. Numerous anastomoses occur between these, especially when the veins become small, or are more distant from the heart.

We find, that their disposition differs according to the organ. In the brain, they form, in great part, the pia mater; and enter the ventricles, where they contribute to the formation of the plexus choroides and tela choroidea. Leaving the organ, we find them situated between the laminæ of the dura mater; when they take the name of *sinuses*. In the spermatic cord, they are extremely tortuous, anastomose repeatedly, and form the *corpus pampiniforme;* around the vagina, they constitute the *corpus retiforme;* in the uterus, the *uterine sinuses*, &c. The veins have three coats in superposition. The *outer coat* is cellular, dense, and very difficult to rupture. The *middle coat* has been termed the *proper membrane of the veins.* The generality of anatomists describe it as composed of longitudinal fibres, which are more distinct in the vena cava inferior than in the vena cava superior; in the superficial veins than in the deep-seated; and in the branches than in the trunks. Magendie states, that he has never been able to observe the fibres of the middle coat; but that he has always seen a multitude of filaments interlacing in all directions; and assuming the

appearance of longitudinal fibres, when the vein is folded or wrinkled longitudinally, which is frequently the case in the large veins. It exhibits no signs of muscularity; even when the galvanic stimulus is applied; yet Magendie suspects its chemical nature to be fibrinous. If so, it is perhaps different from every other tissue in the body. It was remarked, in an early part of this work, that the bases of the cellular and muscular tissues were, respectively, gelatine, and fibrine; and that the various resisting solids could all be brought to one or other of these tissues. To which, then, ought the middle coat of the veins to be attached? Magendie, however, merely states its fibrinous nature to be a suspicion; and, like numerous suspicions, it may be devoid of foundation. Yet we have reason to believe, that the veins are contractile; and the possession of this property would be in accordance with their fibrinous character. Broussais affirms, that this action is one of the principal causes of the return of the blood to the heart. He conceives, that the alternate movements of contraction and relaxation are altogether similar to those of the heart; but that they are so slight as not to have been rendered perceptible by any process in the majority of the veins, although very visible in the vena cava of frogs, where it joins the right auricle. In some experiments by Sarlandière on the circulation, he observed these movements to be independent of those of the heart. After the heart was removed, the contraction and relaxation of the vein continued, for many minutes, in the cut extremity, and even after the blood had ceased to flow.

The *inner coat* is extremely thin and smooth at its inner surface. It is very extensible, and yet presents considerable resistance; bearing a very tight ligature without being ruptured.

In many of the veins, parabolic folds of the inner coat exist, like those in the lymphatics, and inservient to a similar purpose: the free edge of these *valves* is directed towards the centre of the circulation; showing that their office is to permit the blood to flow in that direction, and to prevent its retrogression. They do not seem, however, in many cases, well adapted for the purpose; inasmuch as their size is insufficient to obliterate the cavity of the vein. By most anatomists, this arrangement is considered to depend upon primary organization; but Bichat conceives it to be wholly owing to the state of contraction, or dilatation of the veins at the moment of death. Magendie, however, affirms, that he has never seen the distention of the veins exert any influence on the size of the valves; but that their shape is somewhat modified by the state of contraction or dilatation; and this he thinks probably misled Bichat.

Their number varies in different veins. As a general rule, they are more numerous, where the blood proceeds against its gravity, or where the veins are very extensible, and receive but a feeble support from the circumambient parts, as in the extremities. They are entirely wanting in the veins of the deep-seated viscera; in those of the brain and spinal marrow; of the lungs; in the vena

portæ and in the veins of the kidneys, bladder and uterus. They exist, however, in the spermatic veins; and, sometimes, in the internal mammary, and in the branches of the vena azygos.

On the cardiac side of these valves, cavities or sinuses exist, which appear externally in the form of varices. These dilatations enable the refluent blood to catch the free edges of the valves, and thus to depress them, so as to close the cavity of the vessel; serving, in this respect, precisely the same functions as the sinuses of the pulmonary artery and aorta in regard to the semilunar valves.

The three coats united form a solid vessel,—according to Bichat devoid of elasticity, but, in the opinion of Magendie, elastic in an eminent degree. The elasticity is certainly much less than that of the arteries.

The veins are nourished by *vasa vasorum*, or by small arteries, which have their accompanying veins. Every vessel, indeed, in the body, if we may judge from analogy, appears to draw its nutriment, not from the blood circulating in it, but from small arterial vessels, hence termed *vasa vasorum*. This applies not only to the veins, but to the arteries. The heart, for example, is not nourished by the fluid constantly passing through it; but by vessels, which arise from the aorta, and are distributed over its surface, and in its intimate texture. The coronary arteries and their corresponding veins are, consequently, the *vasa vasorum* of the heart. In like manner, the aorta and all its branches, as well as the veins, receive their vasa vasorum. There must, however, be a term to this; and if our powers of observation were sufficient, we ought to be able to discover a vessel, which must derive its support or nourishment exclusively from its own stores.

The nerves, that have been detected on the veins, are branches of the great sympathetic.

The capacity of the venous system is generally esteemed to be double that of the arterial. It is obvious, however, that we can only arrive at an approximation, and that not a very close one. The size and number of the veins is generally so much greater than that of the corresponding arteries, that, when the vessels of a membranous part are injected, the veins are observed to form a plexus, and, in a great measure, to conceal the arteries: in the intestines, the number is more nearly equal. The difficulty of arriving at any exact conclusion, regarding the relative capacities of the two systems, is forcibly indicated by the fact; that whilst Borelli conceived the preponderance in favour of the veins to be as four to one; Sauvages estimated it at nine to four; Haller at sixteen to nine; and Keil at twenty-five to nine.

There is one portion of the venous system, to which allusion has already been made, which is peculiar. We mean the *abdominal venous*, or *portal*, *system*. All the veins, that return from the digestive organs, situated in the abdomen, unite into a large trunk, called the *vena portæ*. This, instead of passing into a larger vein—into

the vena cava, for example—proceeds to the liver, and ramifies, like an artery, in its substance. From the liver, other veins, called *supra-hepatic*, arise, which empty themselves into the vena cava; and which correspond to the branches of the hepatic artery as well as to those of the vena portæ. The portal system is concerned only with the veins of the digestive organs situated in the abdomen; as, the spleen, pancreas, stomach, intestines and omenta. The veins of all the other abdominal organs,—of the kidney, supra-renal capsules, &c. are not connected with it. The first part of the vena portæ is called, by some authors, *vena portæ abdominalis vel ventralis*, to distinguish it from the hepatic portion, which is of great size, and has been called the *sinus* of the vena portæ.

The blood strongly resembles the chyle in its properties;—the great difference consisting in the colour; and the venous blood, and the chyle, and the lymph become equally converted into the same fluid—arterial blood—in the lungs.

Venous blood, which chiefly concerns us at present, is contained in all the veins, in the right side of the heart, and in the pulmonary artery;—organs which constitute the apparatus of venous circulation. As drawn from the arm, its appearance is familiar to every one. At first, it seems to be entirely homogeneous; but, after resting for some time, it separates into different portions. The colour of venous blood is much darker than that of arterial;—so dark, indeed, as to have had the epithet *black blood* applied to it. Its smell is faint and peculiar; by some compared to a fragrant garlic odour, but it is *sui generis;* its taste is slightly saline and also peculiar. It is viscid to the touch; coagulable, and its temperature has been estimated at 96° of Fahrenheit; simply, we believe, on the authority of the inventor of that thermometric scale, who marked 96° as blood heat. This is too low by at least three or four degrees. Rudolphi, and the German writers in general, estimate it at 29° of Réaumur or "from 98° to 100° of Fahrenheit;" whilst, by the French writers in general, its mean temperature is stated at 31° of Réaumur or 102° of Fahrenheit; Magendie, who is usually very accurate, fixes the temperature of venous blood at 31° of Réaumur, or 102° of Fahrenheit; and that of arterial blood at 32° of Réaumur, or 104° of Fahrenheit. 100° may perhaps be taken as the average. This was the natural temperature of the stomach in the case related by Dr. Beaumont, which has been so often referred to in these pages.

In many animals, the temperature is considerably higher. In the sheep it is 102 or 103°; but it is most elevated in birds. In the duck it is 107°. On this subject, however, further information will be given under the head of *calorification*.

The specific gravity of the blood is differently estimated by different writers. Hence it is probable, that it varies in different individuals, and in the same individual at different periods. Compared with water its mean specific gravity has been estimated, by some, to be

as 1.0527, by others, as 1.0800, to 1.0000. It is stated, however, to have been found as high 1.126; and, in disease, as low as 1.022. It has, moreover, been conceived, that the effect of disease is, invariably, to make it lighter; and that the more healthy the individual, the greater is the specific gravity of the blood; but our information on this point is vague. That it is not always the same is proved by the discrepancy of observers. Boyle estimated it at 1.041; Martine, at 1.045; Jurin at 1.054; Muschenbroek, at 1.056; Denis, at 1.059; Senac, at 1.082; and Berzelius at from 1.052 to 1.057.

When blood is examined with a microscope of high magnifying powers, it appears to be composed of numerous, minute, red particles or globules, suspended in the serum. These red particles have a different shape and dimension, according to the nature of the animal. In the mammalia, they are circular; and, in birds and cold-blooded animals, elliptical. In all animals, they are affirmed, by some observers, to be flattened, and marked in the centre with a luminous point, of a shape analogous to the general shape of the globule. It must, however, be remarked, that here, as in every case, which rests on microscopic observation, the greatest discrepancy prevails, not only as regards the shape but the size of these globules. They were first noticed by Malpighi, and were afterwards more minutely examined by Leeuenhoek, who at first described them, correctly enough, in general terms; but, subsequently, became hypothetical, and advanced the phantasy, that the red particles are composed of a series of globular bodies, descending in regular gradations; each of the red particles being supposed to be composed of six particles of serum; a particle of serum of six particles of lymph, &c. Totally devoid of foundation, as the whole notion was, it was implicitly believed for a considerable period, even until the time when Haller wrote. Hewson described the globules, as consisting of a solid centre, surrounded by a vesicle, filled with a fluid; and to be "as flat as a guinea." Hunter, on the other hand, did not regard them as solid bodies, but as liquids, possessing a central attraction, which determines their shape. Della Torre supposed them to be a kind of disk, or ring, pierced in the centre; whilst Monro conceived them to be circular, flattened bodies, like coins, with a dark spot in the centre, which he thought was not owing to a perforation, as Della Torre had imagined, but to a depression. Cavallo, again, conceived, that all these appearances are deceptive, depending upon the peculiar modification of the rays of light, as affected by the form of the particle; and he concluded, that they are simple spheres. Amici found them of two kinds, both with angular margins; but, in the one, the centre was depressed on both sides; whilst, in the other, it was elevated. The observations of Dr. Young, of Sir Everard Home and Mr. Bauer, and of MM. Prévost and Dumas, accord chiefly with those of Hewson. All these gentlemen consider the red particles to be composed of a central globule, which is transparent and whitish, and of a red envelope,

which is less transparent. Still more recently, however, Dr. Hodgkin and Mr. Lister have denied, that they are spherical, and that they consist of a central nucleus inclosed in a vesicle. They affirm, on the authority of a microscope, which, on comparison, was found equal to a celebrated one, taken a few years ago to Great Britain by Professor Amici, that the particles of human blood appear to consist of circular, flattened, transparent cakes, their thickness being about $\frac{1}{45}$th, part of their diameter. These, when seen singly, appear to be nearly or quite colourless. Their edges are rounded, and being the thickest part, occasion a depression in the middle, which exists on both surfaces. Their view, consequently, appears to resemble that of Monro.

Amidst this discordance, it is difficult to know which view we ought to adopt. The belief in their consisting of circular, flattened, transparent bodies, with a depression in the centre, appears to have the greatest weight of authority in its favour; and that they consist of an external envelope and of a central nucleus, the former of which is red and gives colour to the blood. The nucleus is devoid of colour, and it appears to be independent of the envelope; as, when the latter is destroyed, the central portion preserves its original shape. The nucleus is much smaller than the envelope, being, according to Dr. Young, only about one-third the length, and one-half the breadth of the entire particle.

According to Sir Everard Home, the globules, when enveloped in the colouring matter, are $\frac{1}{1700}$th part of an inch in diameter, requiring 2,890,000 to a square inch; but, when deprived of their colouring matter, they appear to be $\frac{1}{2000}$ part of an in chin diameter, requiring, 4,000,000 of globules to a square inch. From these measurements, the globules, when deprived of their colouring matter, are not quite one-fifth smaller.

The views of MM. Prévost and Dumas, who have investigated this subject with extreme care and signal ingenuity, are deserving of great attention. They conceive the blood to consist essentially of serum, in which a quantity of red particles is suspended; that each of these particles consists of an external red vesicle, which incloses, in its centre, a colourless globule; that, during the progress of coagulation, the vesicle bursts, and permits the central globule to escape; that, on losing their envelope, the central globules are attracted together; that they are disposed to arrange themselves in lines and fibres; that these fibres form a net-work, in the meshes of which they mechanically entangle a quantity of both the serum and of the colouring matter; that these latter substances may be removed by draining, and by ablution in water; that, when this is done, there remains only pure fibrine; and that, consequently, fibrine consists of an aggregation of the central globules of the red particles, while the general mass, that constitutes the crassamentum or clot, is composed of the entire particle.

So far this seems satisfactory; but, we have seen, Dr. Hodgkin does not recognize the existence of external vesicle or of central globule; and he affirms, contrary to the notion of Sir Everard Home and others, that the particles are disposed to coalesce in their entire state. This is best seen, when the blood is viewed between two slips of glass. Under such circumstances, the following appearances, according to Dr. Hodgkin, are perceptible. When human blood, or that of any other animal having circular particles, is examined in this manner, considerable agitation is, at first, seen to take place among the particles; but, as this subsides, they apply themselves to each other by their broad surfaces, and form piles or rouleaux, which are sometimes of considerable length. These rouleaux often again combine amongst themselves,—the end of one being attached to the side of another,—producing, at times, very curious ramifications.

The generality of physiologists consider the fibrine to be one constituent of the blood, and the red particles another. The former is conceived by Müller to be dissolved in the serum.

Microscopical discordances are no less evidenced by the estimates, which have been made of the size of the red globules; yet all are adduced on the faith of positive admeasurements. Leaving out of view the older, and, consequently, it might be presumed, less accurate observations, the following table will show their diameter in human blood, on the authority of some of the most eminent microscopic observers of more recent times.

Sir E. Home, and Bauer, with colouring matter,	$\frac{1}{1700}$th part of an inch.
Eller, - - - - - - -	$\frac{1}{1930}$
Sir E. Home, and Bauer, without colouring matter, - - - -	$\frac{1}{2000}$
Jurin, - - - - - - -	$\frac{1}{2000}$
Müller, - - - - - - -	$\frac{1}{2300}$ to $\frac{1}{3500}$
Hodgkin, Lister, and Rudolphi, - -	$\frac{1}{3000}$
Sprengel, - - - - - -	$\frac{1}{3000}$ to $\frac{1}{3500}$
Cavallo, - - - - - - -	$\frac{1}{3000}$ to $\frac{1}{4000}$
Blumenbach and Senac, - - - -	$\frac{1}{3330}$
Tabor, - - - - - - -	$\frac{1}{3600}$
Wagner, - - - - - - -	$\frac{1}{4000}$
Kater, - - - - - - -	$\frac{1}{4000}$ to $\frac{1}{6000}$
Prévost, and Dumas, - - - -	$\frac{1}{4056}$
Haller, Wollaston, and Weber, - - -	$\frac{1}{5000}$
Young, - - - - - - -	$\frac{1}{6060}$

The blood of different animals is found to differ greatly, in the relative quantity of the red globules it contains; the number seeming to bear a pretty exact ratio with the temperature of the animal. The higher the natural temperature, the greater the proportion of particles; and arterial always contains a much greater proportion than venous blood.

It has been already remarked, that innumerable globules have been found in the chyle. These are colourless; and they have been asserted to be of precisely the same magnitude as the nucleus of the red globule of the blood. It is presumed, too, that the globules of the chyle obtain their colour, and their external envelope on which it depends, in the lungs; and that this is the finish given to the process of digestion. The notion is, however, problematical.

The following table exhibits the diameter of the circular and elliptical globules in different animals, according to MM. Prévost and Dumas.

ANIMALS WITH CIRCULAR GLOBULES.

Animal.	Diameter in fractions of a Millimeter.*
Callitrichus or green Monkey of Africa, - -	$\frac{1}{120}$th
Man, the Dog, Rabbit, Hog, Hedge-hog, Guinea-pig, and Dormouse, - - - -	$\frac{1}{150}$th
The Ass, - - - - - - -	$\frac{1}{167}$th
The Cat, gray and white Mouse, field Mouse, -	$\frac{1}{171}$st
Sheep, Bat, Horse, Mule, Ox, - - - -	$\frac{1}{200}$th
Chamois, Stag, - - - - - -	$\frac{1}{218}$th
Goat, - - - - - - - -	$\frac{1}{288}$th

ANIMALS WITH ELLIPTICAL GLOBULES.

Animal.	Diameter.	
	Long.	Short.
Osprey, Pigeon, - - - - - - -	$\frac{1}{75}$th	$\frac{1}{150}$th
Turkey, Duck, - - - - - - -	$\frac{1}{79}$th	—
Common Fowl, - - - - - - -	$\frac{1}{81}$st	—
Peacock, - - - - - - -	$\frac{1}{85}$th	—
Goose, Goldfinch, Crow, Sparrow, - - -	$\frac{1}{86}$th	—
Titmouse, - - - - - - -	$\frac{1}{100}$th	—
Land Tortoise, - - - - - - -	$\frac{1}{48}$th	$\frac{1}{77}$th
Viper, - - - - - - - -	$\frac{1}{60}$th	$\frac{1}{100}$th
Orvet, - - - - - - - -	$\frac{1}{66}$th	$\frac{1}{115}$th
Coluber of Razomousky, - - - - -	$\frac{1}{51}$st	$\frac{1}{100}$th
Gray Lizard, - - - - - - -	$\frac{1}{66}$th	$\frac{1}{111}$th
Salamandre ceinturée, Crested Salamander, -	$\frac{1}{35}$th	$\frac{1}{56}$th
Common Frog, Toad, Frog with red temples, -	$\frac{1}{45}$th	$\frac{1}{75}$th
Burbot, Minnow, Eel, - - - - - -	$\frac{1}{75}$th	$\frac{1}{125}$th

* A *Millimétre* is equal to In. 0.03937.

When blood is drawn from a vessel, and left to itself, it exhales, so long as it is warm, a fetid vapour consisting of water and animal matter, of a nature not known. This vapour is what has been called the *halitus* of the blood; by Plenck, the *gas animale sanguinis*, which he conceives to be composed of carbon and hydrogen, and to be inservient to many supposititious uses in the economy.

After a time, the blood coagulates, giving off, at the same time, it has been said, a quantity of carbonic acid gas. This disengagement is not evident, when the blood is suffered to remain exposed to the air, except by the apertures or canals formed by its passage through the clot; but it can be collected by placing the blood under the receiver of an air-pump, and exhausting the air. On this fact, however, observers do not all accord. The experiments of Vogel, Brande, Sir E. Home, and Sir C. Scudamore, are in favour of such evolution; and the last gentleman conceives it even to be an essential part of the process; but other distinguished experimenters have not been able to detect it. Neither Dr. John Davy, nor Dr. Duncan, Jr., nor Dr. Christison, could procure it during the coagulation of the blood. Dr. Turner suggests, that the appearance of the carbonic acid, in the experiments of Vogel, Brande, and Scudamore, might easily have been occasioned by casual exposure to the atmosphere, previous to the blood being placed under the receiver; but we have no reason for believing, that this source of fallacy was not guarded against as much by one set of experimenters as by the other. Our knowledge, on this point, is confined then to the fact, that, by some, carbonic acid gas has been found exhaled during the process of coagulation;—by others, not. Recent experiments, by Stromeyer, and by Gmelin, Tiedemann, and Mitscherlich, would seem to decide, that the blood does not give off any free carbonic acid, but that it holds a certain quantity in a state of combination.

During coagulation, the blood separates into two distinct portions; a yellowish liquid, called the serum; and a red solid, known by the name of the *clot*, *cruor*, *crassamentum*, *coagulum*, *placenta*, *insula*, or *hepar sanguinis*. The proportion of the serum to the crassamentum varies greatly in different animals, and in the same animal at different times, according to the state of the system. The latter is more abundant in healthy, vigorous animals, than in those that have been impoverished by depletion, low living, or disease.

The serum is viscous, transparent, of a slightly yellowish hue, and alkaline, owing to the presence of a little free soda. Its smell and taste resemble those of the blood. Its average specific gravity has been estimated at about 1.027. But, on this point also, observers differ. Martine, Muschenbroek, Jurin, and Haller, state it at from 1.022 to 1.037; Berzelius, from 1.027 to 1.029; Lauer, from 1.009 to 1.011; whilst Thackrah found the extremes to be 1.004 and 1.080. At 158° of Fahrenheit, it coagulates; forming, at the same time, numerous cells, containing a fluid, which oozes out from the coagu-

lum of the serum, and is called the *serosity*. It contains, according to Bostock, about $\frac{1}{50}$th of its weight of animal matter, together with a little muriate of soda. Of this animal matter, a portion is albumen, which may be readily coagulated by means of galvanism; but a small quantity of some other principle is present, which differs from albumen and gelatine, and to which Marcet gave the name *muco-extractive matter*, and Bostock, *uncoagulable matter of the blood*—as a term expressive of its most characteristic property.

Serum preserves its property of coagulating, even when largely diluted with water. According to Brande, it is almost pure liquid albumen, united with soda, which keeps it fluid. Consequently, he affirmed, that any reagent, which takes away the soda, will produce coagulation; and that, by the action of caloric, the soda may transform a part of the albumen into mucus.

The action of the galvanic pile coagulates the serum, and forms globules in it analogous to those of the blood.

From the analysis of serum, by Berzelius, it appears to consist in 1000 parts;—of water, 903; albumen, 80; substances soluble in alcohol,—as lactate of soda and extractive matter, muriate of soda and potassa, 10; substances soluble in water,—as soda and animal matter, and phosphate of soda, 4; loss, 3.

Marcet assigns it the following composition:—water, 900 parts; albumen, 86.8; muriates of potassa and soda, 6.6; muco-extractive matter, 4; carbonate of soda, 1.65; sulphate of potassa, 0.35, and earthy phosphates, 0.60;—a result, which closely corresponds with that of Berzelius, who states that the *extractive matter* of Marcet is lactate of soda, united with animal matter.

One of the most recent analyses is by M. Lecanu. According to him, 1000 parts contain,—water, 906 parts; albumen, 78; animal matter, soluble in water and alcohol, 1.69; albumen combined with soda, 2.10; crystallizable fatty matter 1.20; oily matter, 1; hydrochlorate of soda and potassa, 6; subcarbonate and phosphate of soda, and sulphate of potassa, 2.10; phosphate of lime, magnesia and iron, with sub-carbonate of lime and magnesia, 0.91; loss, 1.

Occasionally, the serum presents a whitish hue, which has given rise to the opinion that it contained chyle; but it would seem that this is fatty matter, and that it is always present. In the serum of the blood of spirit drinkers, Dr. Traill found a considerable portion of this substance, which has been considered to favour the notion, that the human body may, by intemperance, become preternaturally combustible; and has been used to account for some of the strange cases of *spontaneous combustion*, or rather of *preternatural combustibility*, which are on record.

The *crassamentum* or *clot* is a solid mass, of a reddish-brown colour, which, when gently washed for some time, under a small stream of water, separates into two portions,—colouring matter and fibrine. As soon as the blood is drawn from a vessel, the colouring matter of the red globules leaves the central nucleus free; these then

unite, as we have seen, and form a net-work, containing some of the colouring matter and many whole globules. By washing the clot in cold water, the free colouring matter and the globules can be removed, and the fibrine will alone remain.

When freed from the colouring matter, the fibrine is solid, whitish, insipid, inodorous, heavier than water, and without action on vegetable colours; elastic, when moist, and becoming brittle by desiccation. It yields, on distillation, much carbonate of ammonia, and a bulky coal, the ashes of which contain a considerable quantity of phosphate of lime, a little phosphate of magnesia, carbonate of lime and carbonate of soda. One hundred parts of fibrine, according to Berzelius, consist of carbon, 53.360; oxygen, 19.685; hydrogen, 7.021; azote, 19.934. Fibrine has been designated by various names. It is the *gluten*, *coagulable lymph*, and *fibre of the blood* of different writers. Its specific gravity is said to be greater than that of the serum; but the difference has not been accurately estimated, and cannot be great. The red particles are manifestly, however, heavier than either, as we find them subsiding during coagulation to the lower surface of the clot, when the blood has flowed freely from the orifice in the vein. Fibrine appears to be the most important constituent of the blood. It exists in animals, in which the red particles are absent, and is the basis of the muscular tissue.

The colouring matter of the blood, called, by some, the *cruor*, *hematine*, *hematosine*, *zoo-hematine*, and *hemachroine*, has been the subject of anxious investigation with the analytical chymist. We have already remarked, that it resides in distinct particles or globules; and, in the opinion of the best observers, in the envelope of those globules. The globules are insoluble in serum, but their colouring principle is dissolved by pure water, acids, alkalies, and alcohol. Raspail asserts, that the globules, themselves, are entirely soluble in pure water, but MM. Donné and Boudet, who repeated his experiments, declare that they are wholly insoluble, and M. Müller is of the same opinion. Great uncertainty has always existed regarding the cause of the colour of the globules. As soon as the blood was found to contain iron, the peroxide of which has a red hue, the colour of the red globules was ascribed to the presence of that metal. Fourcroy and Vauquelin held this opinion, conceiving the iron to be in the state of sub-phosphate; and they affirmed, that this salt may be dissolved in serum by means of an alkali, when the colour of the solution is exactly like that of the blood. Berzelius, however, showed, that the sub-phosphate of iron cannot be dissolved in serum by means of an alkali, except in very minute quantity; and that this salt, even when rendered soluble by phosphoric acid, communicates a tint quite different from that of the red globules. He found, that the ashes of the colouring matter always yielded oxide of iron in the proportion of $\frac{1}{200}$th of the original mass; whence it was inferred, that iron is somehow or other concerned in the production of the colour; but the experiments of Berzelius did not indicate the

state in which that metal exists in the blood. He could not detect its presence by any of the liquid tests.

The views of Berzelius, and the experiments on which they were founded, were not supported by the researches of Mr. Brande. He endeavoured to show, that the colour of the blood does not depend upon iron; for he found the indications of the presence of that metal as considerable in the parts of the blood that are devoid of colour as in the globules themselves; and in each it was present in such small quantity, that no effect, as a colouring agent, could be expected from it. He supposed, that the tint of the red globules is produced by a peculiar, animal colouring principle, capable of combining with metallic oxides. He succeeded in obtaining a compound of the colouring matter of the blood with the oxide of tin; but its best precipitants are the nitrate of mercury and corrosive sublimate. Woollen cloths, impregnated with either of these compounds, and dipped in an aqueous solution of the colouring matter, acquired a permanent red dye, unchangeable by washing with soap. The conclusions of Brande have been supported by Vauquelin, but the fact, connected with the presence of iron, seems to have been finally decided by Engelhart, a young German chymist of distinction, who has demonstrated, that the fibrine and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron; whilst he procured iron from the red globules by incineration. He also succeeded in proving the presence of iron in the colouring matter by the liquid tests; for, on transmitting a current of chlorine gas through a solution of red globules, the colour entirely disappeared, white flocks were thrown down, and a transparent solution remained, in which the peroxide of iron was discovered by the usual reagents. The results, obtained by Engelhart, as regards the quantity of iron, correspond with those of Berzelius. These facts have since been confirmed by Rose of Berlin; and recently, Würzer of Marburg, by pursuing Engelhart's method, by liquid tests, has detected the existence of the protoxide of manganese, likewise.

The proportion of iron does not appear to be more than one-half per cent.; yet, as it is contained only in the colouring matter, there is some reason for believing, that it may be concerned in the coloration of the blood, although probably in the form of oxide. The sulpho-cyanic acid has been detected in the saliva; and this acid, when united with the peroxide of iron, forms a colour exactly like hat of venous blood; so that it has been presumed, it may exist in the blood also; but even should this be found to be the case, there will be still much left to explain; especially as regards the changes effected in the lungs.

Very recently M. Lecanu has subjected the *hematosine* or colouring matter to analysis and found it to be composed of:—loss, representing the weight of the animal matter, 97.742; subcarbonate of soda, alkaline muriates, subcarbonates of lime and magnesia,

and phosphates of lime and magnesia, 1.724; peroxide of iron, 0.534. The result of his researches induces him to conclude, that the colouring matter is a compound of albumen with some colouring substance yet unknown, and which he proposes to call *globuline*, to distinguish it from the hematosine, of which it forms but a part. The globuline yielded on analysis;—loss, 98.26; peroxide of iron, 1.74; and M. Lecanu suggests, that it may result from the combination of some animal matter with certain ferrugineous compounds, analogous to the cyanides.

After all, therefore, our ignorance on this subject is still great; and all that we seem to know is, that the peroxide of iron is contained in the colouring matter of the blood. The redness of the fluid is one of its most obvious characteristics; and we are induced to esteem the change effected in the lungs, as regards colour, of eminent importance. It is, however, no farther so, than as it indicates the accomplishment of the conversion of venous into arterial blood. That there is nothing essential, connected with the mere coloration, is evinced by the fact, that there are many textures, of extreme delicacy, which do not even receive red blood;—the tunica conjunctiva, and the serous membranes, for example. In the insect, again, the blood is transparent; in the caterpillar, of a greenish hue; and, in the internal vessels of the frog, yellowish. In man, it differs according to numerous circumstances; and the colour of the skin, which is partly dependent upon these differences, thus becomes an index of the state of individual health or disease. In the *morbus cæruleus*, *cyanopathy* or *blue disease*, the whole surface is coloured blue, especially in those parts where the skin is delicate, as on the lips,—owing to a communication existing between the right and left sides of the heart, so that the blood can pass from one to the other, without proceeding through the lungs;—and the appearance of the jaundiced is familiar to all.

The formation of the clot, and its separation from the serum, are manifestly dependent upon the fibrine; which, by assuming the solid state, gives rise to the *coagulation* of the blood;—a phenomenon, which has occasioned much fruitless speculation and experiment; yet, if the views of Raspail were proved to be correct, it would be sufficiently simple. The alkaline character of the blood, and the production of coagulation by a dilute acid leave no doubt, in his mind, that an alkali is the menstruum of the albumen of the blood. The alkaline matter, he thinks, is soda, but more especially ammonia, of which, he says, authors take no account; but whose different salts are evident under the microscope. Now, "the carbonic acid of the atmospheric air and the carbonic acid, which forms in the blood by its avidity for oxygen, saturate the menstruum of the albumen, which is precipitated as a clot. The evaporation of the ammonia, and, above all, the evaporation of the water of the blood, which issues smoking from the vein, likewise set free an additional quantity of dissolved albumen, and the mass coagulates the more quickly as the blood is less aqueous."

The process of coagulation is influenced by exposure to the air. Hewson affirmed, that it is promoted by such exposure, but Hunter was of an opposite opinion. If the atmospheric air be excluded,—by filling a bottle completely with recently drawn blood, and closing the orifice with a good stopper,—coagulation is retarded. Yet Sir C. Scudamore mentions the singular fact, that if blood be confined within the exhausted receiver of an air-pump, the coagulation is accelerated; and MM. Gmelin, Tiedemann, and Mitscherlich found, that, under such circumstances, both venous and arterial blood coagulated as perfectly as under ordinary circumstances. The presence of air is certainly not essential to the process.

Experiments have also been made on the effect produced by different gases on the process of coagulation; but the results have not been such as to afford much information. It is asserted, for example, by some, that it is promoted by carbonic acid, and certain other of the irrespirable gases, and retarded by oxygen: by others, the reverse is affirmed; whilst Sir Humphry Davy and M. Schröder inform us, that they could not perceive any difference, in the period of the coagulation of venous blood, when it was exposed to azote, nitrous gas, oxygen, nitrous oxide, carbonic acid, hydrocarbon, or atmospheric air.

The time, necessary for coagulation, is affected by temperature. It is promoted by warmth; retarded, but not prevented, by cold. Hewson froze blood, newly drawn from a vein, and afterwards thawed it; when it first became fluid, and then coagulated as usual. Hunter made a similar experiment with the like result. It is obviously, therefore, not from simple refrigeration that the blood coagulates. Sir C. Scudamore found, that blood, which begins to coagulate in four minutes and a half, in a temperature of 53° Fahr., undergoes the same change in two minutes and a half at 98°; and that, which coagulates in four minutes at 98°, Fahr., becomes solid in one minute at 120°. On the contrary, blood, which coagulates firmly in five minutes at 60° Fahr., will remain quite fluid for twenty minutes, at the temperature of 40° Fahr., and requires upwards of an hour for complete coagulation. The observations of Gendrin were similar. As a general rule, it would seem, from the experiments of Hewson, Schröder and Thackrah, that coagulation takes place most readily at the temperature of the body.

During the coagulation of the blood, a quantity of caloric is disengaged. Fourcroy relates an experiment, in which the thermometer rose no less than 11° during the process; but as certain experiments of Hunter appeared to show, that no elevation of temperature occurred, the observation of Fourcroy was disregarded. It has, however, been confirmed by some experiments of the late Dr. Gordon, of Edinburgh, in which the evolution of caloric, during coagulation, was rendered more manifest, by moving the thermometer during the formation of the clot, first into the coagulated,

and afterwards into the fluid part of the blood, when he found, that by this means, he could detect a difference of 6°; which continued to be manifested for twenty minutes after the process had commenced. In repeating the experiment on blood, taken from a person labouring under inflammatory fever, the thermometer was found to rise 12°. Sir C. Scudamore affirms, that the rate at which blood cools is distinctly slower than it would be, were no caloric evolved; and that he observed the thermometer to rise one degree at the commencement of coagulation. On the other hand, Dr. John Davy and Mr. Thackrah accord with Hunter in the belief, that the increase of temperature, from this cause, is very slight or null. *Again* we have to deplore the discordance amongst observers; and it will perhaps have struck the reader more than once, that such discordance applies as much to topics of direct observation as to those of a theoretical character. The discrepance, regarding anatomical and physical *facts*, is even more glaring than that which prevails amongst physiologists in accounting for the corporeal phenomena; a circumstance, which tends to confirm the notion promulgated by one of the most distinguished teachers of his day, that "there are more false facts in medicine, (and the remark might be extended to the collateral or accessary sciences,) than false theories."

There are certain substances, again, which, when added to the blood, prevent or retard its coagulation. Hewson found, that the sulphate and muriate of soda, and the nitrate of potassa were amongst the most powerful salts in this respect. The muriate of ammonia and a solution of potassa have the same effect. On the contrary, the coagulation is promoted by alum, and by the sulphates of zinc and copper. How these salts act on the fibrine, so as to prevent its particles from coming together, it is not easy to explain. But these are not the only inscrutable circumstances that affect the coagulation of the blood. Many causes of sudden death have been considered to have this effect:—lightning and electricity; a blow upon the stomach; injury of the brain; the bites of venomous animals; certain narcotico-acrid vegetable poisons; also, excessive exercise and violent mental emotions, when they suddenly destroy, &c. Many of these affirmations doubtless rest on insufficient proof. Sir C. Scudamore, for example, asserts that lightning has not this effect. Blood, through which electric discharges were transmitted, coagulated as quickly as that which was not electrified; and, in animals, killed by the discharge of a powerful galvanic battery, the blood in the veins was always found in a solid state.

We shall find, hereafter, that these affirmations have been considered evidence that the blood may be *killed;* and, consequently, that it is possessed of life. All the phenomena, indeed, of coagulation, inexplicable in the present state of our knowledge, have been invoked to prove this position. The preservation of the fluid state, whilst circulating in the vessels, although agitation, when it is out of the body, does not prevent its coagulation, has been regarded, of itself, sufficient evidence in favour of the doctrine. Dr. Bostock,

indeed, asserts, that perhaps the most obvious and consistent view of the subject is, that fibrine has a natural disposition to assume the solid form, when no circumstance prevents it from exercising this inherent tendency. As it is gradually added to the blood, particle by particle, whilst that fluid is in a state of agitation in the vessels, it has no opportunity, he conceives, of concreting; but when it is suffered to lie at rest, either within or without the vessels, it is then liable to exercise its natural tendency. It is not our intention, at present, to enter into the subject of the vitality of the blood. The general question will be considered in a subsequent part of this work. We may merely observe, that, by the generality of physiologists, the blood is presumed, either to be endowed with a principle of vitality, or to receive from the organs, with which it comes in contact, a vital impression or influence, which, together with the constant motion, counteracts its tendency to coagulation. Even Magendie,—who is unusually and properly chary in having recourse to this method of explaining the *notum per ignotius*,—affirms, that instead of referring the coagulation of the blood to any physical influence, it should be considered as an essentially vital process; or, in other words, as affording a demonstrative proof, that the blood is endowed with life.

Within a few years, Vauquelin has discovered in the blood a considerable quantity of fatty matter; of a soft consistence; and which he, at first, regarded as fat; but Chevreul, after careful investigation, has declared it to be identical with the matter of the brain and nerves, and to form the singular compound of an *azoted fat*. Prévost and Dumas, Ségalas and others have likewise demonstrated the existence of urea in the blood of animals, from which the kidneys had been removed. Chemical analysis is, indeed, adding daily to our stock of information on this matter; and is exhibiting to us, that many of the substances, which compose the tissues, exist in the very state in the blood, in which we meet with them in the tissues. This is signally shown in the analysis of the blood by M. Lecanu, who found it to be composed—in 1000 parts—of water, 786.590; albumen, 69.415; fibrine, 3.565; colouring matter, 119.626; crystallizable fatty matter, 4.300; oily matter, 2.270; extractive matter, soluble in alcohol and water, 1.920: albumen combined with soda, 2.010; chlorides of sodium and potassium, alkaline phosphate, sulphate, and subcarbonates, 7.304; subcarbonate of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron, 1.414; loss, 2.586.

On this analysis, Dr. Prout has remarked, that *gelatine* is never found in the blood, or in any product of glandular secretion, and he adds, that a given weight of gelatine contains at least three or four per cent. less carbon than an equal weight of albumen. Hence, the production of gelatine from albumen, he conceives, must be a *reducing* process. We shall see, under the head of respiration, what application he makes of these considerations.

Lastly,—some interesting considerations on the blood have been published by Dr. Benjamin G. Babington. They form the subject of a valuable paper, in the "Medico Chirurgical Transactions," of London, Vol. XVI. Part II., and are entitled "Some considerations with respect to the blood, founded on one or two simple experiments on that fluid." The principal experiment was the following:—

He drew blood, in a full stream, from the vein of a person labouring under acute rheumatism, into a glass vessel filled to the brim. On close inspection, a colourless fluid was immediately perceived around the edge of the surface, and, after a rest of four or five minutes, a bluish appearance was observed forming an upper layer on the blood, which was owing to the subsidence of the red particles to a certain distance below the surface, and the consequent existence of a clear liquor between the plane of the red particles and the eye. A spoon, previously moistened with water, was now immersed into the upper layer of liquid, by a gentle depression of one border. The liquid was thus collected quite free from red particles, and was found to be an opalescent, and somewhat viscid solution, perfectly homogeneous in appearance. By repeating the immersion, the fluid was collected in quantity, and transferred to another vessel. That, which Dr. Babington employed, was a bottle, holding about 180 grains, of globular form, with a narrow neck and perforated glass stopper.

The solution, with which the globular bottle was filled, though quite homogeneous at the time it was thus collected, was found, after a time, to separate into two parts, viz. into a clot of fibrine, which had the precise form of the bottle into which it was received, and a clear serum, possessing all the usual characters of the fluid.

From this experiment, Dr. Babington infers, that buffed blood, to which we shall have to refer under another head, consists of only two constituents, the red particles, and a liquid to which he gives the name—*liquor sanguinis.*

It has long been observed, that the blood of inflammation is longer in coagulating than the blood of health, and that the last portion of blood drawn from an animal, coagulates the quickest. The immediate cause of this buffy coat is thus explained by Dr. Babington. The blood, consisting of *liquor sanguinis* and insoluble red particles, preserves its fluidity long enough to permit the red particles, which are of greater specific gravity, to subside through it. At length, the *liquor sanguinis* separates, by a general coagulation and contraction, into two parts, and this phenomena takes place uniformly throughout the liquor. That part of it, through which the red particles had time to fall, furnishes a pure fibrine or buffed crust, whilst the portion, into which the red particles had descended, furnished the coloured clot. This, in extreme cases, may be very loose at the bottom, from the great number of red particles collected there, each of which has supplanted its bulk of fibrine, and consequently dimin

ished its firmness in that part. There is, however, with this limitation, no more fibrine in one part of the blood than another.

It is a well known fact, that the shape of the vessel, into which the blood is received, influences the depth of the buff. The space, left by the gravitation of the red particles, bears a proportion to the whole perpendicular depth of the blood, so that in a shallow vessel scarcely any buff may appear, whilst the same blood in a deep vessel would have furnished a crust of considerable thickness; but Dr. Babington asserts, that even the quantity of the crassamentum is dependent, within certain limits, on the form of the vessel. If this be shallow the crassamentum will be abundant, if approaching the cube or sphere in form, it will be scanty. The difference is owing to the greater or less distance of the coagulating particles of fibrine from a common centre, which causes a more or less powerful adhesion and contraction of these particles. This is matter of practical moment, inasmuch as blood is conceived to be thick or thin, rich or poor, in reference to the quantity of crassamentum; and pathological views are entertained in consequence of conditions, which after all depend not on the blood itself, but on the vessel into which it is received.

To remove an objection, that might be urged against a general conclusion deduced from the experiment cited,—that it was made upon blood in a diseased state, Dr. Babington received some healthy blood into a tall glass vessel half filled with oil, which enabled the red particles to subside more quickly than would otherwise have been the case. This blood was found to have a layer of *liquor sanguinis*, which formed a buffy coat, whilst a portion of the same blood, received into a similar vessel, in which there was no oil, had no buff. Hence, it would appear, that healthy blood is similarly constituted as blood disposed to form a buffy coat, the only difference being, that the former coagulates more quickly than the latter.

Dr. Babington was also led to believe, from his experiments, that fibrine and serum do not exist, as such, in circulating blood, but that the *liquor sanguinis*, when removed from the circulation, and no longer subjected to the laws of life, has then, and not before, the property of separating into fibrine and serum. This separation, which may be regarded as the death of the blood, may, under disease, take place within the body, but never, he thinks, consistently with healthy action.

Other facts connected with the vital fluid; its quantity, &c. will be considered, after we have inquired into the changes produced on the venous blood in the lungs, through the agency of respiration.

Physiology of Venous Absorption.

Whilst the opinion prevailed universally, that the lymphatics are the sole agents of absorption; the fluid, circulating in the veins, was considered to consist entirely of the residue of the arterial

blood, after it had passed through the capillary system, and been subjected to the different nutritive processes there effected. We have already seen, however, that the drinks are absorbed by the mesenteric veins; and we shall hereafter find, that various other substances enter the venous system by absorption. It is obvious, therefore, that the venous blood cannot be simply the residue of arterial blood; and we can thus account for the greater capacity of the venous system than of the arterial.

The facts, which were referred to, when considering the absorption of fluids from the intestinal canal, may have been sufficient to show, that the veins are capable of absorbing; as the odorous and colouring properties of substances were distinctly found in the mesenteric veins. A question arises, whether any vital elaboration is concerned, as in the case of the chyle, or whether the fluid, when it attains the interior of the vessel, is the same as without? Adelon, —who, with many of the German physiologists, believes in both venous and lymphatic absorption, and venous and chyliferous absorption,—conceives, that a vital action takes place at the very mouths of the venous radicles, precisely similar to that which is presumed to be exerted at the mouths of the lymphatic and chyliferous radicles. In his view, consequently, an action of elaboration is exerted upon the fluid, which becomes, in all cases, converted into venous blood, at the very moment of absorption, as chyle and lymph are elaborated under similar circumstances.

On the other hand, Magendie, Fodéra and others maintain, that the substance soaks through the vessel, when possessed of the necessary tenuity; that this act of imbibition is purely physical, and consists in the introduction of the absorbed materials through the pores of the veins by capillary attraction. In their view, therefore, the fluid within the vessel should be the same as that without.

In favour of the vital action of the veins we have none of that evidence, which strikes us in regard to the chyliferous and lymphatic vessels. In these last we invariably find fluids, identical—in all essential respects—in sensible and chymical characters: and never containing extraneous matter, if we make abstraction of certain salts, which have been occasionally met with in the thoracic duct. In the veins, on the other hand, the sensible properties of odorous and colouring substances have been apparent. But, it may be remarked, the fluid, flowing in the veins, is as identical in composition as the chyle or the lymph: this is true. It must, however, be recollected, that the greater part of it is the residue of the arterial blood; and that its hue and other sensible properties are such as to disguise any absorbed fluid, not itself possessing strong characteristics. The fact, then—now indisputable—that various substances, placed outside of the veins, have been detected in the blood within, is not only a proof, that the veins absorb; but that no action of elaboration has been exerted on the absorbed fluid. Of

this we have the most manifest proof in some experiments by Magendie, detailed in his *Précis Elémentaire de Physiologie.* In exhibiting to his class the mode in which medicines act upon the system, he showed, on a living animal, the effects of introducing a quantity of water, of the temperature of 104° Fah., into the veins. In performing this experiment, it occurred to him to notice what would be the effect produced by artificial plethora on the phenomena of absorption. Having injected nearly a quart of water into the veins of a dog of middle size, he placed in the cavity of the pleura a small dose of a substance with the effects of which he was familiar, and was struck with the fact, that these did not exhibit themselves for several minutes after the ordinary period. He immediately repeated the experiment and with a like result. In several other experiments, the effects appeared at the ordinary time, but were manifestly feebler than they ought to have been from the dose of the substance employed, and were kept up much longer than usual.

In another experiment, having introduced as much water as the animal could bear without perishing,—which was about two quarts,—the effects did not occur at all. After having waited nearly half an hour for their developement, which generally required only about two minutes, he inferred, that if the distention of the blood-vessels was the cause of the defect of absorption, provided the distention were removed, absorption ought to take place. He immediately bled the animal largely in the jugular; and, to his great satisfaction, found the effects manifesting themselves as the blood flowed.

He next tried, whether, if the quantity of blood were diminished at the commencement of the experiment, absorption would be more rapid; and the result was as he anticipated. An animal was bled to the extent of about half a pound; and the effects, which did not ordinarily occur until after the second minute, appeared before the thirtieth second. As the results of these experiments seemed to show, that absorption is evidently in an inverse ratio to the degree of vascular distention, Magendie inferred, that it is effected physically; is dependent upon capillary attraction; and that it ought to take place as well after death as during life. To prove this, he instituted the following experiments:—

He took a portion of the external jugular vein of a dog, about an inch long and devoid of branches. Removing carefully the surrounding cellular tissue, he attached to each of its extremities a glass tube, by means of which he kept up a current of warm water within it. He then placed the vein in a slightly acid liquor, and carefully collected the fluid of the current. During the first few minutes, the fluid exhibited no change; but, in five or six minutes, it became sensibly acid. This experiment was repeated on veins taken from the human subject, with the same results; and not only with veins but with arteries. Similar experiments were next

made on living animals. He took a young dog, about six weeks old, whose vessels were thin, and, consequently, best adapted for the success of the experiment, and exposed one of its jugular veins. This he dissected entirely from the surrounding matter, and especially from the cellular tissue and the minute vessels, which ramified upon it, and placed it upon a card in order that there might be no point of contact between it and the surrounding parts. He then let fall upon its surface and opposite the middle of the card a thick, watery solution of nux vomica,—a substance, which exerts a powerful action upon dogs. He took care that no particle of the poison touched anything but the vein and card, and that the course of the blood, within the vessel, was free. Before the end of three minutes, the effects, which he expected, appeared,—at first feebly, but afterwards with so much activity, that he had to prevent fatal results by inflating the lungs.

The experiment was repeated on an older animal with the same effects; except that, as might be expected, they were longer in exhibiting themselves, owing to the greater thickness of the parietes of the veins.

Satisfied, as regarded the veins, he now directed his attention to the arteries; and with like results. They were, however, slower in appearing than in the case of the veins, owing to the tissue of the arteries being less spongy than that of the veins. It required more than a quarter of an hour for imbibition to be accomplished.

In one of the rabbits, which died under the experiment, they had an opportunity of discovering, that the absorption could not have been effected by any small veins, which had escaped dissection. One of the carotids—the subject vessel of the experiment—was taken from the body; when the small quantity of blood, adherent to its inner surface, was found by Magendie, and his friends who assisted at the experiment, possessing the extreme bitterness which characterizes the nux vomica.

These experiments were sufficient to prove the fact of imbibition by the large vessels, both in the dead and the living state. His attention was now directed to the small vessels, which seemed, *a priori*, favourable to the same action from their delicacy of organization. He took the heart of a dog, which had died the day before, and injected, into one of the coronary arteries, water at the temperature of 86° of Fah. The water readily returned by the coronary vein into the right auricle, whence it was allowed to flow into a vessel. Half an ounce of water, slightly acidulated, was now placed in the pericardium. At first, the injected fluid did not exhibit any signs of acidity; but, in five or six minutes, the evidences of it were unequivocal.

From these facts, Magendie draws the too exclusive deduction, that "all blood-vessels, arterial and venous, dead or living, large or small, possess a physical property, capable of perfectly accounting for the principal phenomena of absorption." We shall endeavour to

show, that it explains only certain varieties of absorption,—those in which the vessel receives the fluid unmodified,—but that it is unable to account for absorptions, in which an action of selection and elaboration is necessary.

Since these experiments were performed, others have been instituted by M. Ségalas and Fodéra; from which the latter physiologist attempts to show, that exhalation is, simply, *transudation* of substances from the interior of vessels to the exterior; and that *absorption* is *imbibition*, or the passage of fluids from the exterior to the interior. The facts, adduced by Fodéra in support of his views, will be considered under the head of secretion. They chiefly go to show the facility with which substances penetrate the different vascular parietes and other tissues of the body; an action, which he found to be singularly accelerated by the galvanic influence. Some prussiate of potassa was injected into the cavity of the pleura; and sulphate of iron was introduced into the abdomen of a living animal. Under ordinary circumstances, it requires five or six minutes, before the two substances meet by imbibition through the diaphragm; but the admixture is instantaneous if the diaphragm be subjected to a slight galvanic current. The same fact is observed, if one of the liquids be placed in the urinary bladder, and the other in the abdomen; or the one in the lung, and the other in the cavity of the pleura. It was farther found, that, according to the direction of the current, the union took place in one or other cavity. Dr. Bostock, in commenting on these cases, thinks it must be admitted, that they "go very far to prove that membranes, *perhaps, even during life*, and certainly after death, before their texture is visibly altered, have the power of permitting the transudation of certain fluids." That such imbibition occurs during life, appears to us indisputably proved. If the clear and decisive experiments of Magendie and Fodéra do not establish it; the additional testimony,—afforded by Lawrence, Coates and Harlan; by Dutrochet, Mitchell and others,—commands it. By the different rates of penetrativeness of different fluids, and of permeability of different tissues, as exhibited in the essays of the last gentleman, we can explain, why imbibition may occur in one set of vessels and not in another; and why there may not be the same tendency to transude from the vessel, after the fluid has entered it by imbibition, as has been suggested by Dr. Bostock; indeed, the constant current, established in the interior of the vessel, would be a sufficient reply to this suggestion.

Adelon, again, affirms, that we ought, under the view of imbibition, to find imbibed substances in the arteries and lymphatics, also. A sufficient objection to this would be,—the comparative tardiness, with which the former admit of the action; and the selection, and, consequently, refusal, exerted by the latter; but even here we occasionally find evidences of adventitious imbibition; as in the case of salts, which have been detected in the thoracic duct, when introduced into the cavity of the abdomen.

The two following experiments of Dr. Mitchell, which are analogous to numerous others, performed in the investigation of this subject, ratify the fact of imbibition in the living tissues.

A quantity of solution of acetate of lead was thrown into the peritoneal cavity of a young cat; and sulphuretted hydrogen was passed, at the same time, into the rectum. In four minutes, the poisonous gas killed the animal. Instantly on its death, the peritoneal coat of the intestines, and the parietes of the cavity in contact with them, were found lined with a metallic precipitate, which adhered to the surface, and was removable by nitric acid, moderately diluted. It was the characteristic precipitate of sulphuretted hydrogen, when acting on lead.

In another experiment on a cat, a solution of acetate of lead was placed in the thorax, and sulphuretted hydrogen in the abdomen. Almost immediately after the entrance of the sulphuretted hydrogen into the abdominal cavity, death ensued. On inspecting the thoracic side of the diaphragm, which was done as quickly as possible, the tendinous part of it exhibited the leaden appearance of the precipitate by sulphuretted hydrogen.

It may be concluded, then, that all the living tissues imbibe the liquid matters which come in contact with them; and that the same occurs to solid matters, provided they are soluble in the humours, and especially in the serum of the blood.

Within the last few years, Dr. Barry,—in different memoirs laid before the *Académie Royale de Médecine*, the *Académie Royale des Sciences* of Paris, and the *Medico-Chirurgical Society* of London,—has maintained, that the whole function of external absorption is a physical effect of atmospheric pressure; and "that the circulation, in the absorbing vessels and in the great veins, depends upon this same cause in all animals possessing the power of contracting and dilating a cavity, around that point, to which the centripetal current of their circulation is directed." In other words, it is the opinion of this gentleman, that, at the time of inspiration, a tendency to a vacuum is produced in the chest by its expansion; and as the atmospheric pressure, externally, thus ceases to be counterbalanced, the pressure without occasions the flow of blood towards the heart, along the veins.

The consideration of the forces that propel the blood will afford us an opportunity of saying a few words on this view; at present, we shall only observe, that he ascribes absorption,—which he explicitly states to be, in his opinion, extra vital,—to the same cause. In proof of this, he instituted numerous experiments, in which the absorption of poisons from wounds appeared to take place or to be suspended, according as the wounds continued, as he conceived, exposed to atmospheric pressure, or were freed from its influence by the application of a cupping-glass. The same quantity of poison, which, under ordinary circumstances, destroyed an animal in a few seconds, was rendered completely innocuous by the ex-

hausted vessel; and what is singular, even when the symptoms had commenced, the application of the cupping-glass had the effect of speedily and completely removing them;—a fact of essential importance in its therapeutical relations.

In commenting on the conclusions of Dr. Barry, Messrs. Addison and Morgan, who maintain the doctrine,—that all poisonous agents produce their specific effects upon the brain, and general system, through the sentient extremities of nerves, and through the sentient extremities of nerves only; and that, when introduced into the current of the circulation in any way, their effects result from the impression made upon the sensible structure of the blood-vessels, and not from their direct application to the brain itself,—contend that the soft parts of the body, which are covered by an exhausted cupping-glass, must necessarily, from the pressure of the edges of the glass, be deprived, for a time, of all connexion, both nervous and vascular, with the surrounding parts;—that the nerves must be partially or altogether paralyzed by compression of their trunks, and that, from the same cause, all circulation through the veins and arteries situated within the area of the glass must cease;—that the rarefaction of the air within the glass being still farther increased by means of the small pump attached to it, the fluids, in the divided extremities of the vessels, are forced into the vacuum, and, with these fluids, either a part or the whole of the poison, which had been introduced; and that, in such a condition of parts, the compression, on the one hand, and the removal of the poison from the wound on the other, will sufficiently explain the result of the experiment, either according to the views of those who conceive the impression to be made on the nerves of the blood-vessel, or of those who conceive that the agent must be carried along with the fluid of the circulation to the part to be impressed.

Such would seem to be the main facts, regarding the absorbent action of the veins, which rests on as strong evidence as we possess regarding any of the functions of the body; yet, in the recent treatise on animal and vegetable physiology, by Dr. Roget, we find it passed by without a comment! We have still to inquire into the agents of internal, and adventitious absorption.

Sect. IV.—INTERNAL ABSORPTION.

On this point but few remarks will be necessary, after the exposition of the different vascular actions, concerned in absorption This term comprehends, as we have already remarked,—*interstitial absorption*, and the *absorption of recrementitial*, and of *excrementitial fluids*.—The *first* comprises the agency, by which the different textures of the body are decomposed and conveyed into the mass of the blood. It will be considered more at length under the head of Nutrition; the *second*, that of the various fluids, effused into cavities;

and the *third*, that which is effected on the excretions in their reservoirs or excretory ducts.

All these must be effected by one of the two sets of vessels, previously described;—the lymphatics, or veins, or both. Now we have attempted to show, that an action of selection and elaboration is exerted by lymphatic vessels; whilst we have no evidence of such action in the case of the veins. It would follow, then, that all those varieties of internal absorption, in which the substance, when received into the vessel, possesses different characters from those it had when without, must be executed by lymphatics; whilst those, in which no conversion occurs, take place by the veins. In the constant absorption, and corresponding deposition, which is incessantly going on in the body, the solid parts must be reduced to their elements, and a new compound be formed; inasmuch as we never find bone, muscle, cartilage, membrane, &c. existing in these states in any of the absorbed fluids; and it is probable, therefore, that, at the radicles of the lymphatic vessels, they are all converted into the same fluid—the lymph—as the heterogeneous substances, existing in the intestinal canal, afford to the lacteals the elements of a fluid, the character of which is always identical. On the other hand, when the recrementitial fluid consists simply of the serum of the blood, more or less diluted, there can be no obstacle to its passage immediately through the coats of the veins by imbibition, and to its absorption, by the lymphatic vessels also. In the case of the excrementitious fluids, there is reason to believe, that absorption simply removes some of their aqueous portions, and this, it is obvious, can be effected directly by the veins, through imbibition. The facts, connected with the absorption of substances from the interior of the intestine, have clearly shown, that the chyliferous vessels alone absorb chyle, and that the drinks and adventitious substances pass into the mesenteric veins. These apply, however, to *external* absorption only; but similar experiments and arguments have been brought forward by the supporters of the two opinions, with regard to substances placed on the peritoneal surface of the intestine, and other parts of the body. Whilst some affirm, that they have entered the lymphatics, others have only been able to discover them in the veins. John Hunter, having injected water, coloured with indigo, into the peritoneal cavity of animals, saw the lymphatics, a short time afterwards, filled with liquid of a blue colour. In animals, which had died of pulmonary or abdominal hæmorrhage, Mascagni found the lymphatics of the lungs and peritoneum filled with blood; and he asserts, that having kept his feet for some hours in water, swelling of the inguinal glands supervened, with transudation of a fluid through the gland, coryza, &c. Desgenettes observed the lymphatics of the liver containing a bitter, and those of the kidneys a urinous, lymph. Sömmering detected bile in the lymphatics of the liver; and milk in those of the axilla. Dupuytren relates a case,

which Magendie conceives to be much more favourable to the doctrine of absorption by the lymphatic vessels than any of the others. A female, who had an enormous tumour at the upper and inner part of the thigh, with fluctuation, died at the Hôtel Dieu of Paris, in 1810. A few days before her death, inflammation occurred in the subcutaneous cellular tissue at the inner part of the tumour. The day after dissolution, Dupuytren opened the body. On dividing the integuments, he noticed white points on the lips of the incision. Surprised at the appearance, he carefully dissected away some of the skin, and observed the subcutaneous cellular tissue overrun by whitish lines, some of which were as large as a crow's quill. These were evidently lymphatics, filled with puriform matter. The glands of the groin, with which these lymphatics communicated, were injected with the same matter. The lymphatics were full of the fluid, as far as the lumbar glands; but neither these glands nor the thoracic duct presented any trace of it.

On the other hand, multiplied experiments have been instituted, by throwing coloured and odorous substances into the great cavities of the body; and these have been found always in the veins, and never in the lymphatics.

To the experiments of Hunter, objections have been urged, similar to those adduced against his experiments to prove the absorption of milk by the lacteals; and some sources of fallacy have been pointed out. The blue colour, which the lymphatics seemed to him to possess, and which was ascribed to the absorption of indigo, was noticed in the experiments of Messrs. Harlan, Lawrence, and Coates; but they discovered that this was an optical illusion. What they saw was the faint blue, which transparent substances assume, when placed over dark cavities. Mr. Mayo has also affirmed, that the chyliferous lymphatics always assume a bluish tint a short time after death, even when the animal has not taken indigo. The cases of purulent matter, &c., found in the lymphatics, may be accounted for by the morbid action having produced disorganization of the vessel, so that the fluid could enter the lymphatic directly; and, if once within, its progression can be readily understood.

Lastly, Magendie affirms, that Dupuytren and himself performed more than one hundred and fifty experiments, in which they submitted to the absorbent action of serous membranes a number of different fluids, and never found any of them within the lymphatic vessels. The substances, thus introduced into the serous cavities, produced their effects more promptly, in proportion to the rapidity with which they are capable of being absorbed. Opium exerted its narcotic influence, wine produced intoxication, &c., and Magendie found, from numerous experiments, that the ligature of the thoracic duct in no respect diminished the promptitude with which these effects appeared.

The partisans of lymphatic absorption, however, affirm, that even if these substances are met with in the veins, it by no means follows,

that absorption has been effected by that order of vessels; for, as we have seen, the lymphatics, they assert, have frequent communications with the veins; and, consequently, they may still absorb and convey their products into the venous system.

In reply to this, it may be urged, that all the vessels—arterial, venous, and lymphatic—appear to have communication with each other; but that there is no reason to believe, that the distinct offices, performed by them, are, under ordinary circumstances, interfered with; and, again, where would be the necessity for these intermediate lymphatic vessels, seeing that imbibition is so readily effected by the veins? The axiom—*quod fieri potest per pauca, non debet fieri per multa*—is here strikingly appropriate. The lymphatics, too, as we have endeavoured to show, exert an action of selection and elaboration on the substances exposed to their agency; but, in the case of venous absorption, we have not the slightest evidence that any such selection exists,—odorous and coloured substances retaining, within the vessel, the properties they had without. Lastly, where would be the use of the distinct, lymphatic circulation opening into the thoracic duct, seeing that the absorbed matters might enter the various venous trunks directly through these supposititious, communicating lymphatics; and ought we not occasionally to be able to detect in the lymphatic trunks, at least some evidence of those substances, which their fellows are supposed to take up and convey into the veins? These carrier lymphatics have obviously been devised to support the tottering fabric of lymphatic absorption; undermined, as it has been, by the powerful facts and reasonings, that have been adduced, in favour of absortion by the veins.

It would result, then, from the whole of the preceding history of absorption, that we are of opinion, that the chyliferous and lymphatic vessels form only chyle and lymph, refusing all other substances; that the veins admit every liquid, which possesses the necessary tenuity; and that, whilst all the absorptions, which require the substances, acted upon, to be decomposed and transformed, are effected by the chyliferous and lymphatic vessels; those that demand no alteration are accomplished directly through the coats of the veins by imbibition; and we shall see, that such is the case with several of the transudations or exhalations.

Sect. V.—ACCIDENTAL ABSORPTION.

The experiments, to which reference has been made, have shown, that many substances, adventitiously introduced into various cavities, or placed in contact with different tissues, have been rapidly absorbed into the blood, without experiencing any transformation.

Within certain limits, the external envelope of the body admits of this function; but by no means to the same extent as its prolon-

gation, which lines the different excretory canals. The absorption of drinks is sufficient evidence of the activity of the function, as regards the gastro-intestinal mucous membrane. The same may be said of the pulmonary mucous membrane. Through it, the oxygen passes to reach the blood in the lungs, as well as the carbonic acid in its way outwards. Aromatic substances, such as spirit of turpentine, breathed for some time, are detected in the urine, proving that their aroma has been absorbed; and it is by absorption that contagious miasmata probably produce their pestiferous agency. Not only do the tissues, as we have seen, suffer imbibition by fluids, but by gases also: the experiments of Chaussier, and Mitchell astonish us by the rapidity and singularity of the passage of gases through the various tissues;—the rapidity varying according to the permeability of the tissue, and the penetrative power of the gas.

On the subject of *cutaneous absorption*, much difference of opinion has prevailed; some asserting it to be possible to such an extent, that life might be preserved, for a time, by nourishing baths. It has also been repeatedly affirmed, that rain has calmed the thirst of shipwrecked mariners, who have been, for some time, deprived of water. It is obvious, from what we know of absorption, that, in the first of these cases, the water only could be absorbed; and even the possibility of this has been denied by many. Under ordinary circumstances, it can happen to a trifling extent only, if at all; but, in these extraordinary cases, where the system has been long devoid of its usual supplies of moisture, and where we have reason to believe, that the energy of absorption is increased, such imbibition may be possible. Sanctorius, Von Gorter, Keil, Mascagni and others believe, that this kind of absorption is not only frequent but easy. It has been affirmed, that, after bathing, the weight of the body has been manifestly augmented; and the last of these individuals has adduced many facts and arguments to support the position. Bichat was under the impression, that, in this way, he imbibed the tainted air of the dissecting-room, in which he passed a large portion of his time. To avoid an objection, that might be urged against this idea, —that the miasmata might have been absorbed by the air-passages, he so contrived his experiment, as, by means of a long tube, to breathe the fresh outer air, and he found, that the evidence, which consisted in the alvine evacuations having the smell of the miasmata of the dissecting room, still continued. It is obvious, however, that such an experiment would hardly admit of satisfactory execution. J. Bradner Stuart found, after bathing in infusions of madder, rhubarb, and tumeric, that the urine was tinged with these substances. A garlic plaster affected the breath, when every care was taken, by breathing through a tube connected with the exterior of the apartment, that the odour should not be received into the lungs. Dr. Thomas Sewall found the urine coloured, after bathing the feet in infusion of madder, and the hands in infusions of madder and rhu-

barb. Dr. Mussey proved, that if the body be immersed in a decoction of madder, the substance may be detected in the urine, by using the appropriate alkaline tests; and Dr. John Edwards of Paris is, also, in favour of absorption being carried on by the skin to a considerable extent.

To deny cutaneous absorption altogether is impossible. It is one of the ways, in fact, by which we introduce one of our most active remedial agents into the system,—and it has not unfrequently happened, where due caution has not been used, that the noxious effects of different mineral and other poisons have been developed by their application to the surface, but it is by no means common or easy, when the cuticle is sound, unless the substance employed possesses unusually penetrating properties. Chaussier found, that to kill an animal, it is sufficient to make sulphuretted hydrogen gas act on the surface of the body, taking care that none gets into the air-passages: the researches of Dr. Mitchell have also shown, that this gas is powerfully penetrant. Unless, however, the substances, in contact with the epidermis, are of such a nature as to attack its chymical composition, there is usually no sensible absorption.

It is only of comparatively late years, that physiologists have ventured to deny, that the water of a bath, or the moisture from a damp atmosphere, is taken up under ordinary circumstances; and if, in such cases, the body appears to have increased in weight, it is affirmed, and with great appearance of truth, that this is owing to some diminution in the cutaneous transpiration. It is, indeed, probable, that one great use of the epidermis is to prevent the inconveniences to which we should necessarily be liable, were such absorption easy. This is confirmed by the fact, that if the skin be deprived of the epidermis, and the vessels which creep on the outer surface of the true skin, be thus exposed, absorption occurs as rapidly as elsewhere. To insure this result in inoculation and vaccination, the matter is always placed beneath the cuticle; and, indeed, the small vessels are generally slightly wounded, so that the virus gets immediately into the venous blood. Yet, it is proper to remark, that the lizard, whose skin is scaly, after having lost weight by exposure to the air, recovers its weight and plumpness when placed in contact with water, and if the scaly skin of the lizard permits such absorption, Dr. Edwards thinks it impossible not to attribute this property to the cuticle of man. When the epidermis is removed, and the system is affected by substances placed in contact with the true skin, we have the *endermic method* of medication.

Séguin instituted a series of experiments to demonstrate the absorbent or non-absorbent action of the skin. His conclusion was, that water is not absorbed, and that the epidermis is a natural obstacle to that action. To discover whether this was the case as regarded other fluids, he made trial of some individuals labouring under venereal affections. These persons immersed their feet and

legs in a bath, composed of sixteen pints of water and three drachms of corrosive sublimate, for an hour or two, twice a day. Thirteen, subjected to the treatment for twenty-eight days, gave no signs of absorption; the fourteenth was manifestly affected, but he had itchy excoriations on the legs; and the same was the case with two others. As a general rule, absorption exhibited itself in those only whose epidermis was not in a state of integrity. At the temperature of 74° Fahrenheit, however, the sublimate was occasionally absorbed, but never the water.

From other experiments of Séguin, it appeared evident, that the most irritating substances, and those most disposed to combine with the epidermis, were partly absorbed, whilst others were apparently not. Having weighed a drachm, (seventy-two grains, *poids de marc*,) of calomel, and the same quantity of camboge, scammony, salt of alembroth and tartar emetic, Séguin placed an individual on his back, washed the skin of the abdomen carefully, and applied to it these substances, at some distance from each other, covering each with a watch-glass, and maintaining the whole *in situ* by a linen roller. The heat of the room was kept at 65°. Séguin did not leave the patient, in order that the substances should not be displaced; and he protracted the experiment to ten hours and a quarter. The glasses were then removed, and the substances carefully collected and weighed. The calomel was reduced to 71 1-3 grains. The scammony weighed 71 3-9; the camboge, 71; the salt of alembroth, 62 grains;* and the tartar emetic 67 grains.

It requires, then, in order that matters shall be absorbed by the skin, that they shall be kept in contact with it, so as to penetrate its pores, or the channels by which the cutaneous transpiration exudes; or else that they shall be forced through the cuticle by friction, —the *iatraleptic mode*, adopted for introducing mercury into the system. In this way, the substance comes in contact with the cutaneous veins, and enters them probably by imbibition.

Nearly about the period that Séguin was engaged in his experiments, Dr. Rousseau, of Philadelphia, contested the existence of absorption through the epidermis, and attempted to show, in opposition to the experiments we have detailed, that the pulmonary organs, and not the skin, are the passages by which certain substances enter the system. By cutting off all communication with the lungs, which he effected by breathing through a tube communicating with the atmosphere on the outside of the chamber, he found, that although the surface of the body was bathed with the juice of garlic or the spirit of turpentine, none of the qualities of these fluids could be detected, either in the urine, or in the serum of the blood.

From the subsequent experiments, performed by Dr. Rousseau, assisted by Dr. Samuel B. Smith, and many of which Professor

* Several pimples were excited on the part to which it was applied.

Chapman witnessed, the following results were deduced. *First*, That of all the substances employed, madder and rhubarb are those only that affect the urine; the latter of the two more readily entering the system; and *secondly*, that the power of absorption is limited to a very small portion of the surface of the body. The only parts, indeed, that seemed to possess it, were the spaces between the middle of the thigh and hip, and between the middle of the arm and shoulder. Topical bathing, with a decoction of rhubarb or madder, and poultices of these substances, applied to the back, abdomen, sides, or shoulders, produced no change in the urine; nor did immersion of the feet and hands in a bath of the same materials, for several hours, afford the slightest proof of absorption.

From these and other facts,—sufficiently discrepant it is true,—we are justified in concluding, with Dr. Chapman, that although the subject is not, perhaps, absolutely decided, enough has been done to demonstrate, that cuticular absorption is not easy, and that whenever it does happen, it cannot be deemed the effort of a natural function, but we can readily conceive, from the facility with which water soaks through animal tissues, that if the animal body be immersed sufficiently long in it, and especially if the vessels have been previously drained, imbibition might take place to a considerable extent. But this would be a mere physical absorption, and could be effected as well in the dead as the living body.

Amongst the adventitious absorptions have been classed all those that are exerted upon substances retained in their excretory ducts, or situated in parts not natural to them. The bile, arrested in one of the biliary ducts, affords us, in jaundice, a familiar example of such absorption, and of the positive existence of the bile in the blood-vessels; although the yellow colour has been supposed, by some, to be caused by an altered condition of the red globules of the blood, and not by the presence of bile in the blood-vessels. This condition of the red globules will account for some of the symptoms,—as the yellow colour of the skin, and of the urine,—but it does not explain the clayey appearance, which the evacuations present, and which, we think, has been properly ascribed to the absence of the biliary secretion. We have, likewise, examples of this kind of absorption, where blood is effused into the cellular membrane, as in the case of a common bruise, or in the accumulation of fluid in the various cavities, all of which are found to disappear by time, and, probably, entirely through the agency of the veins;—the serous portion being taken up first, with some of the colouring matter, and, ultimately, the fibrine. In the case of an accumulation of the serous fluid, which naturally lubricates cavities, it is precisely of such a character as to be imbibed with facility, and probably passes into the veins, in this manner;—the functions of exhalation and absorption consisting, here, mainly of transudation and imbibition.

But absorption is not confined to these fluids. It must, of course,

be exerted on all morbid deposits; and it is to excite the action of the absorbents, that our remedial means are directed; the agents, belonging to this class, being termed *sorbefacients*. This absorption is of the interstitial kind; and, as the morbid formation has probably to be reduced to its elements, and undergo an action of elaboration, it ought to be referred to lymphatic agency.

To conclude the function of absorption.—All the products we have seen,—whether the absorption may have been chyliferous, lymphatic or venous,—are united in the venous system, and form part of the venous blood. This fluid must, consequently, be variable in its composition, in proportion to the quantity of heterogeneous materials taken up by the veins, and the activity of the chyliferous and lymphatic absorptions. It is also clear, that, between the parts of the venous system into which the supra-hepatic veins,—loaded with the products of intestinal absorption,—enter, and the opening of the thoracic duct into the subclavian, the blood must differ materially from that which flows in other parts of the system.

All, however, undergo admixture in their passage through the heart; and all are converted into arterial blood by the function, which will next engage us,—that of *Respiration*.

RESPIRATION.

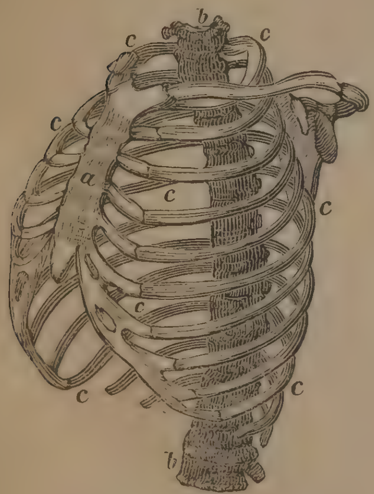
The consideration of the function of absorption has shown us how the different products of nutritive absorption reach the venous blood. By simple admixture with this fluid they do not become converted into a substance, capable of supplying the losses, sustained by the frame from the different excretions. Nothing is better established than the fact, that no being, and no part of any being, can continue its functions unless supplied with blood, which has become *arterial*, by exposure to air. It is, in the lungs, that the absorbed matters undergo their final conversion into that fluid;—by a function, which has been termed *hæmatosis*, and which is the great object of that we have now to investigate—*Respiration*. This conversion is occasioned by the venous blood of the pulmonary vessels coming in contact with the air in the air-cells of the lungs, during which contact, the blood gives to the air some of its constituents, and, in return, the air parts with some of its elements to the blood.

To comprehend this mysterious process, we must be acquainted with the pulmonary apparatus, as well as with the properties of atmospheric air, and the mode in which the contact between it and the blood is effected.

Anatomy of the Respiratory Organs.

The *thorax* or *chest* contains the lungs, which are the great agents of respiration. It is of a conical shape, the apex of the cone being formed by the neck, and the base by a muscle, which has already been referred to, more than once,—the *diaphragm*.

Fig. 114.



The Thorax.

a. Sternum or breast-bone.—*b*. *b*. The spine.—*c*. *c*. *c*. *c*. The ribs.

The osseous frame work, Fig. 114, is formed, *posteriorly*, of twelve dorsal vertebræ; *anteriorly*, of the sternum, originally composed of eight or nine pieces; and *laterally*, of twelve ribs on each side, passing from the vertebræ to, or towards, the sternum. Of these, the seven uppermost extend the whole distance from the spine to the breast-bone, and are called the *true* or *sternal ribs;* sometimes, the *vertebro-sternal*. They become larger as they descend, and are situated more obliquely in regard to the spine. The other

five, called *false* or *asternal*, do not proceed as far as the sternum; but their cartilages join that of the seventh true rib, whilst the two lowest have no union with those above them, and are therefore called *floating ribs.* These false ribs become shorter and shorter as they descend; so that the seventh true rib may be regarded as the common base of two cones, formed by the true and false ribs respectively.

The different bones, constituting the thorax, are so articulated as to admit of motion, and thus to allow of dilatation and contraction of the cavity.

The motion of the vertebræ on each other has been described under another head. It is not materially concerned in the respiratory movements. The articulation of the ribs with the spine and sternum demands attention. They are articulated with the spine in two places,—at the *capitulum* or head, and at the *tubercle.* In the former of these, the extremity of the ribs, encrusted with cartilage, is received into a depression, similarly encrusted, at the side of the spine. One half of this depression is in the body of the upper vertebræ; the other half in the one beneath it; and, consequently, partly in the inter-vertebral fibro-cartilage between the two. The joint is rendered secure by various ligaments; but it can move readily up and down on the spine. In the first, eleventh, and twelfth ribs, the articulations are with single vertebræ respectively. In the second articulation, the tubercle of the rib, also encrusted with cartilage, is received into a cavity in the transverse process of each corresponding vertebra; and the joint is rendered strong by three distinct ligaments. In the eleventh and twelfth ribs, this articulation is wanting.

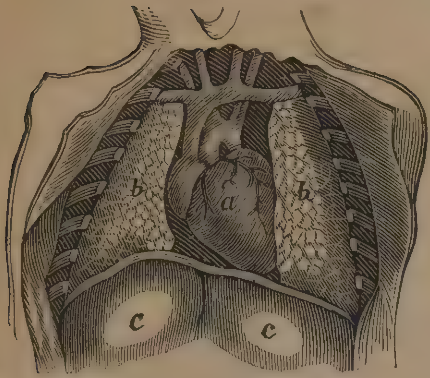
The articulation of the ribs with the sternum is affected by an intermediate cartilage, which becomes gradually longer, from the first to the tenth rib, as seen in figure 114. The end of the cartilage is received into a cavity at the side of the sternum; and the junction is strengthened by an anterior and posterior ligament. This articulation does not admit of much motion; but the existence of a synovial membrane shows, that it is destined for some.

The cavity of the thorax is completed by muscles. In the intervals between the ribs are two planes of muscles, whose fibres pass in inverse directions, and cross each other. These are the *intercostal muscles.*

The diaphragm forms the septum between the thorax and abdomen. Above, the cavity is open; and through the opening numerous vessels and nerves enter.

The muscles, concerned in the respiratory function, are numerous. The most important of these is the *diaphragm.* It is attached, by its circumference, around the base of the chest; but its centre rises into the thorax; and, during its state of relaxation, forms an arch, the middle of which is opposite the inferior extremity of the sternum. It is tendinous in its centre, and is attached by two fas-

Fig. 114.



Thoracic viscera.

a. The heart.—*b*. *b*. The lungs.—*c*. *c*. The diaphragm.

ciculi, called *pillars*, to the spine,—to the bodies of the two first lumbar vertebræ. It has three apertures; the one before for the passage of the vena cava inferior; and two behind, between the pillars, for the passage of the œsophagus and aorta.

The other great muscles of respiration are the *serratus posticus inferior*, the *serratus posticus superior*, the *levatores costarum*, the *intercostal muscles*, the *infra-costales*, and the *triangularis sterni* or *sterno-costalis;* but, in an excited condition of respiration, all the muscles, that raise and depress the ribs, directly or indirectly, participate—as the *scaleni*, *sterno-mastoidei*, *pectoralis*, (*major* and *minor*,) *serratus major anticus*, *abdominal muscles*, &c.

In the structure of the *lungs*, as Măgendie has remarked, nature has resolved a mechanical problem of extreme difficulty. The problem was,—to estabilsh an immense surface of contact between the blood and the air, in the small space occupied by the lungs. The admirable arrangement adopted consists in this,—that each of the minute vessels, in which the pulmonary artery terminates, and the pulmonary veins originate, is surrounded on every side by the air. The lungs are two organs of considerable size, situated in the lateral parts of the chest, and are subdivided into lobes and lobules, the shape and number of which cannot be readily determined.

They are termed *right* and *left* respectively, according to the side of the cavity of the chest which they occupy. The former consists of three lobes; the latter of two. Each of these exactly fills the corresponding cavity of the pleura; and they are separated from each other by a duplicature of the pleura—(the serous membrane that lines the chest, and is reflected over the lungs;)—and by the heart. The colour of the lungs is generally of a marbled blue; and the exterior is furrowed by figures of a hexagonal shape. The appearance is not, however, the same at all ages, and under all circumstances. In infancy, they are of a pale red; in youth, of a darker colour; and in old age, of a livid blue.

The elements, that compose the lungs, are;—the ramifications of the trachea; those of the pulmonary artery and of the pulmonary veins, besides the organic elements, that appertain to every living structure,—arteries, veins, lymphatics, nerves and cellular tissue.

The ramifications of the windpipe form the cavity of the organ of respiration. The trachea is continuous with the larynx from which it receives the external air conveyed to it by the mouth and nose. It passes down to the thorax, at the anterior part of the neck, and bifurcates opposite the second dorsal vertebra, forming two large canals, called *bronchi*. One of these goes to each lung; and, after numerous subdivisions, becomes imperceptible: hence, the multitudinous speculations, that have been indulged, regarding the mode in which the bronchial ramifications terminate. Malpighi believed, that they form vesicles, at the inner surface of which the pulmonary artery ramifies. Reisseisen describes the vesicles as of a cylindrical, and somewhat rounded, figure; and he states, that they do not communicate with each other. Helvetius, on the other hand, affirmed, that they end in cells, formed by the different constituent elements of the lungs,—the cells having no determinate shape, or regular connexion with each other; whilst Magendie asserts, that the minute bronchial division, which arrives at a lobe, does not enter it, but terminates suddenly as soon as it has reached the parenchyma; and he remarks, that as the bronchus does not penetrate the spongy tissue of the lung, it is not probable, that the surface of the cells, with which the air comes in contact, is lined by a prolongation of the mucous coat, which forms the inner membrane of the air-passages. Certain it is, that the most attentive examination has failed to detect its presence.

The ramifications of the pulmonary artery are another constituent element of the lung. This vessel arises from the right ventricle of the heart, and, at a short distance from that organ, divides into two branches; one passing to each lung. Each branch accompanies the corresponding bronchus in all its divisions; and, at length, becomes capillary and imperceptible. Its termination has, also, given rise to conjecture. Malpighi conceived it to end at the mucous surface of the bronchi, in an extremely delicate network, which he called *rete mirabile*. This was also the opinion of Reisseisen. According to others, the pulmonary artery, in its ultimate ramifications, is continuous with two kinds of vessels,—the capillary extremities of the pulmonary veins; and the exhalants engaged in the secretion of the pulmonary transpiration. Bichat admits, at the extremities of the pulmonary artery, and between that artery and the veins of the same name, vessels of a more delicate character, which he conceives to be the agents of hæmatosis, and which he calls the *capillary system of the lungs*. All that we know is, that the air gets a ready access to the blood in the pulmonary artery; but, with regard to the precise arrangement of the means of such access, we are ignorant. The same may be said of the third constituent of the lungs—the *pulmonary veins*. Their radicles manifestly communicate freely with those of the pulmonary artery; but they equally escape detection. When we observe them, they are found uniting, to constitute larger and larger veins,

until they ultimately end in four large trunks, which open into the left auricle of the heart.

In addition to these organic constituents, the lung, like other organs, receives arteries, veins, lymphatics, and nerves. It is not nourished by the blood of the pulmonary artery, which is not adapted for that purpose, seeing that it is venous. The *bronchial arteries* are its nutritive vessels. They arise from the aorta, and are distributed to the bronchi.

Around the bronchi, and near where they dip into the tissue of the lung, a number of lymphatic glands exist, the colour of which is almost black, and with which the few lymphatic vessels, that arise from the superficial and deep-seated parts of the lung, communicate. The efferent vessels of these glands Haller has traced into the thoracic duct.

The nerves, distributed to the lungs, proceed chiefly from the eighth pair or pneumogastric. A few filaments of the great sympathetic are also sent to them. The eighth pair—after having given off the superior laryngeal nerves, and some twigs to the heart—interlaces with numerous branches of the great sympathetic, and forms an extensive nervous net-work, called the *anterior pulmonary plexus.* After this, the nerve gives off the recurrents, and interlaces a second time with branches of the great sympathetic, forming another net-work, called the *posterior pulmonary plexus.* It then proceeds to the stomach, where it terminates. From these two plexuses the nerves proceed, that are distributed to the lungs. These accompany the bronchi, and are spread chiefly on the mucous membrane of the air tubes. The lung likewise receives some nerves directly from the three cervical ganglions of the great sympathetic, and from the first thoracic ganglion.

In addition to these, a distinct system of nerves—the *respiratory system* of Sir Charles Bell, described in the first volume of this work,—is distributed to the multitude of muscles, which are associated in the respiratory function, in a voluntary or involuntary manner. This system includes one of the nerves just referred to—the eighth pair. The various nerves, composing it, are intimately connected, so that, in forced or hurried respiration, in coughing, sneezing, &c. they are always associated in action.

Lastly, the lungs are constituted, also, of cellular tissue, which has been termed *interlobular tissue;* but it does not differ from cellular tissue in other parts of the body.

Such are the constituent elements of the pulmonary tissue; but, with regard to the mode, in which they are combined to form the intimate texture of the lung, we are uninstructed. We find, that the lobes are divided into lobules, and these, again, seem to be subdivided almost indefinitely, forming an extremely delicate spongy tissue, the areolæ of which can only be seen by the aid of the microscope. They communicate with each other, and are enveloped, apparently, by the cellular tissue which separates the lobules.

Magendie inflated a portion of lung; dried and cut it in slices, in order that he might examine the deep-seated cells. These appeared to him to be irregular, and to be formed by the final ramifications of the pulmonary artery, and the primary ramifications of the pulmonary veins; the cells of one lobule communicating with each other, but not with those of another lobule. Professor Horner, of the University of Pennsylvania, has attempted to exhibit, by a well-conceived and well-executed preparation, that this communication between the cells is lateral. After filling the pulmonary arteries and the pulmonary veins with minute injection, the ramifications of the bronchi, with the air-cells, were distended to their natural size, by an injection of melted tallow. The latter, being permitted to cool, the lung was cut into slices, and dried. The slices were subsequently immersed in spirit of turpentine, and digested, at a moderate heat, for several days. By this process, all the tallow was removed, and the parts, on being dried, appeared to exhibit the air-cells empty, and, seemingly, of their natural size and shape. Preparations, thus made, appear to show the air-cells to be generally about the twelfth of a line in diameter, and of a spherical shape, the cells of each lobule communicating freely, like the cells of fine sponge, by lateral apertures. The lobules, however, only communicate by branches of the bronchi, and not by contiguous cells.

This would seem to negative the presumption of some anatomists and physiologists,—as Blumenbach, Cuvier, &c.,—that each air-cell is insulated, communicating only with the minute bronchus, that opens into it; whilst it confirms the views of Haller, Monro Secundus, Boyer, Sprengel, Magendie, and others; but it is impossible to decide positively, where all is so minute. Many anatomists, by the term air-cell, mean simply the ultimate termination of a bronchus.

The surface afforded by the air-cells is immense. Hales supposed them to be polyhedral, and about one-hundredth part of an inch in diameter. The surface of the bronchi he estimated at 1035 square inches; and that of the air-cells at 20,000. Keil estimated the number of cells to be 1,744,186,015; and the surface 21,906 square inches; and Lieberkühn has valued it at the enormous amount of 1500 square feet! All that we can derive from these mathematical conjectures, is, that the extent of surface is surprising, when we consider the small size of the lungs themselves.

Each lung is covered by the *pleura*,—a serous membrane, analogous to the peritoneum,—and in birds a prolongation of the latter. This membrane is reflected from the adjacent surface of the lung to the pericardium which covers the heart, and is then spread over the interior paries of the half of the thorax to which it belongs; lining the ribs and intercostal muscles, and covering the convex or upper surface of the diaphragm. There are, consequently, two pleuræ, each of which is confined to its own half of the thorax, lining its cavity, and covering the lung. Behind the sternum, however, they

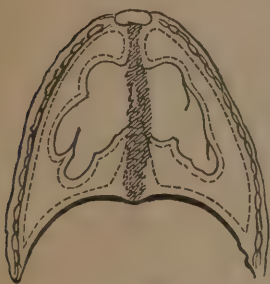
are contiguous to each other, and form the partition, called *mediastinum*, which extends between the sternum and spine. In figure 116, the dotted lines exhibit the two cavities of the pleura, and the middle space between is the mediastinum. Within this septum, the heart, enveloped by the pericardium, is situated, and separates the pleuræ considerably from each other. Anatomists generally subdivide the mediastinum into two regions. One, passing from the front of the pericardium to the sternum, called the *anterior mediastinum;* the other, from the posterior surface of the pericardium to the dorsal vertebræ,—the *posterior mediastinum;* and, by some, the part, which is within the circuit of the first ribs, is termed *superior mediastinum.* The second of these contains the most important organs,—the lower end of the trachea, œsophagus, aorta, vena azygos, thoracic duct, and pneumogastric nerves.

Fig. 116.

Reflections of the Pleura.

The portion of the pleura, covering each lung, is called the *pleura pulmonalis;* that, which lines the thorax, *pleura costalis.* The mode, in which the two are connected to form one whole, is shown by the dotted line in figure 117, resembling a section of the chest. It is obvious, that, as in the case of the abdomen, the viscera are not in the cavity of the pleura, but external to it; and that there is no communication between the sac of one side and that of the other.

Fig. 117.



Reflections of the Pleura.

The use of the pleura is to attach the lungs, by their roots, to their respective cavities, and to facilitate their movements. To aid this effect, the membrane is always lubricated by a fluid, exhaled from its surface. The other surface is attached to the lung in such a manner, that air cannot get between it and the parietes of the thorax.

Recently, Dr. Stokes, of Dublin, has described a proper fibrous tunic of the lungs. In the healthy state, this capsule, although possessing great strength, is transparent, a circumstance in which it differs from the fibrous capsule of the pericardium, and which, Dr. Stokes thinks, has probably led to its having been overlooked.

This tunic invests the whole of both lungs; covers a portion of the great vessels; and the pericardium seems to be but its continuation, endowed, in that particular situation, with a greater degree of

strength, for purposes that are obvious. It covers the diaphragm where it is more opaque; in connexion with the pleura, it lines the ribs; and, turning, it forms the mediastina, which are thus shown to consist of four layers,—two serous and two fibrous. It seems, that Dr. Hart, of Dublin, has, for years, demonstrated this tunic to his class.

It was, at one time, the prevalent belief, that air always exists in the cavity of the chest. Galen supported the opinion by the fact, that, having applied a bladder, filled with air, to a wound, which had penetrated the chest, the air was drawn out of the bladder at the time of inspiration. This was also maintained by Hamberger, Hales, and numerous others. The case, alluded to by Galen, is insufficient to establish the position, inasmuch as we have no evidence, that the wound did not also implicate the pulmonary tissue. Since the time of Haller, who opposed the prevalent doctrine by facts and reasoning, the belief in the absence of air in the cavity of the pleura is generally considered to be entirely established. It is obvious, that its presence there would materially interfere with the dilatation of the lungs, and thus be productive of much inconvenience; besides, anatomy instructs us, that the lungs lie in pretty close contact with the pleura costalis. When the intercostal muscles are dissected off, and the pleura costalis is exposed, the surface of the lungs is seen in contact with that transparent membrane; and, when the pleura is punctured, the air rushes in, and the lungs retire, in proportion as the air is admitted. This occurs in cases of injuries inflicted upon the chest of the living animal. Moreover, if a dead or living body be placed under water, and the pleura be punctured, so as not to implicate the lungs, it has been found by the experiments of Brunn, Sprögel, Caldani, Sir John Floyer, Haller, and others, that not a bubble of air escapes,—which would necessarily be the case, if air were contained in the cavity of the pleura.

Of Atmospheric Air.

The globe is surrounded everywhere, to the height of fifteen or sixteen leagues, by a rare and transparent fluid, called *air;* the total mass of which constitutes the *atmosphere.*

Atmospheric air, although invisible, can be proved to possess the ordinary properties of matter; and, amongst these, weight. It also partakes of the character of a fluid, adapting itself to the form of the vessel in which it is contained, and pressing equally in all directions.

As air is possessed of weight, it results, that every body on the earth's surface must be subjected to its pressure; and as it is elastic or capable of yielding to pressure, the part of the atmosphere, near the earth's surface, must be denser than that above it. As a body, therefore, ascends, the pressure will be diminished; and this accounts for the different feelings experienced by those who ascend

lofty mountains, or voyage in balloons into the higher strata of the atmosphere. When M. De Sayve ascended the cone of the crater on the summit of Etna, he felt so much indisposed, that he was obliged to stop at almost every step, experiencing extraordinary debility in the limbs, with pain in the region of the heart, and a feeling,—as he expresses it,—as if he were passing into an element not in accordance with his nature. De Saussure, Joseph Hamel, Dr. Edward Clark, and Captain Sherwill, on the Alps; Baron Ramond on the Pyrenees; Baron Humboldt on the Andes; Du Petit Thouars on Mount Bernard in the Isle of Bourbon; and Lieutenant Gerard and Mr. Fraser on the Himală Mountains, experienced similar inconvenience.

Dr. Edwards ascribes part, at least, of the effect produced upon the breathing at great elevations, to the increased evaporation which takes place from the skin and lungs; and his view is confirmed by the fact, that in many aerial voyages great inconvenience has been sustained from this cause.

The pressure of the atmosphere, at the level of the sea, is the result of the whole weight of the atmosphere, and is capable of sustaining a column of water thirty-four feet high, or one of mercury of the height of thirty inches,—as in the common *barometer*. This is equal to about fifteen pounds avoirdupoise on every square inch of surface; so that the body of a man of ordinary stature, the surface of which Haller estimates to be fifteen square feet, sustains a pressure of 32,400 pounds. Yet, as the elasticity of the air within the body exactly balances or counteracts the pressure from without, he is not sensible of any pressure.

The experiments of Davy, Dalton, Gay Lussac, Humboldt, Despretz, and others, have shown, that pure atmospheric air is composed essentially of two gases—*oxygen* and *azote;* which exist in it, in the proportion of 21 of the former to 79 of the latter: Dr. Thomson, whose analysis is the most recent and satisfactory, says 20 of oxygen to 80 of azote or nitrogen; and these proportions have been found to prevail in the air whencesoever taken;—whether from the summit of Mont Blanc, the top of Chimborazo, the sandy plains of Egypt, or from an altitude of 23,000 feet in the air. Nor has chymical analysis been enabled to detect the presence of any emanation from the soil of the most insalubrious regions, or from the bodies of those labouring under the most contagious diseases,—malignant and *material* as such emanations unquestionably must be.

The uniformity of the proportion of the oxygen to the nitrogen in the atmosphere has led to the conclusion, that as there are many processes, which consume the oxygen, there must be some natural agency, by which a quantity of oxygen is produced equal to that consumed. The only source, however, by which oxygen is known to be supplied, is in the process of vegetation. A healthy plant absorbs carbonic acid during the day; appropriates the carbon to its own

necessities, and gives off the oxygen with which it was combined. During the night, an opposite effect is produced. The oxygen is then taken from the air, and carbonic acid given off; but the experiments of Davy and Priestley show, that plants, during the twenty-four hours, yield more oxygen than they consume. It is impossible to look to this as the great cause of equilibrium between the oxygen and azote. Its influence can extend to a small distance only; and yet the uniformity has been found to prevail, as we have seen, in the most elevated regions, and in countries, whose arid sands never admit of vegetation.

In addition to the oxygen and azote,—the principal constituent; of atmospheric air,—another gas exists in a very small proportions but yet is always present. This is *carbonic acid.* It was found by De Saussure on Mont Blanc, and by Humboldt in air brought down by Garnerin the aeronaut, from the height of several thousand feet. The proportion is estimated by Dalton not to exceed the $\frac{1}{1000}$th or $\frac{1}{1400}$th of its bulk.

These, then, may be looked upon as the constituents of atmospheric air. There are certain substances, however, which are adventitiously present in variable proportions; and which, with the constitution of the atmosphere as to density and temperature, are the causes of general or local salubrity, or the contrary. Water is one of these. The quantity, according to De Saussure, in a cubic foot of air, charged with moisture at 65° Fahr., is 11 grains. Its amount in the atmosphere is very variable, owing to the continual change of temperature to which the air is subject; and even when the temperature is the same, the quantity of vapour is found to vary, as the air is very rarely in a state of saturation. The varying condition as to moisture is indicated by the *hygrometer.* From a comparison of numerous observations, Gay Lussac affirms, that the mean hygrometric state of the atmosphere is such, that the air holds just one-half the moisture necessary for its saturation. In his celebrated aerial voyage, he found the air to contain but one-eighth of the moisture necessary for saturation. This is the greatest degree of dryness ever noticed.

It has been presumed, that the hygrometric condition of the atmospheric air has more agency in the production of disease than either the barometric or thermometric. It is not easy to say which exerts the greatest influence: probably all are equally concerned, and when we have a union of particular barometric, thermometric, hygrometric and electric conditions, we have certain epidemics existing, which do not prevail under any other combination. When the air is dry, we feel a degree of elasticity and buoyancy; whilst if it be saturated with moisture,—especially during the heat of summer,—languor and lassitude, and indisposition to mental or corporeal exertion are excited.

In addition to aqueous vapour, numerous emanations from animal and vegetable substances must be generally present, especially in the lower strata of the atmosphere; by which the salubrity of the

air may be more or less affected. All living bodies, when crowded together, deteriorate the air so much as to render it unfit for the maintenance of the healthy function. If animals be kept crowded together in ill-ventilated apartments, they speedily sicken. The horse becomes attacked with *glanders;* fowls with *pep,* and sheep with a disease peculiar to them if they be too closely folded. This is probably a principal cause of the insalubrity of cities compared with the country. In them, the air must necessarily be deteriorated by the impracticability of due ventilation.

One of the greatest evidences we possess of the positive insalubrity of towns is in the case of the young. In London, the proportion of those that die annually under five years of age, is as much as thirty-eight per cent., and under two years, twenty-eight per cent.; in Paris under two years of age, twenty-five per cent; and in Philadelphia and Baltimore, rather less than a third. These estimates may be considered approximations; the proportions varying somewhat, according to the precise year in which they have been taken.

Manifest, however, as is the existence of some deleterious principle in these cases, it has always escaped the researches of the chymist.

Lastly,—Air is indispensably requisite for organic existence. No being,—animal or vegetable,—can continue to live without a due supply of it; nor can any other gas be substituted for it. This is proved by the fact, that all organized bodies cease to exist, if placed *in vacuo.* They require, likewise, renovation of the air, otherwise they die; and if the residual air be examined, it is found to be diminished in quantity, to have lost a part of its oxygen, and to have received, in its place, a gas, which is totally unfit for life,—*carbonic acid.* The experiments of Hales prove this as regards vegetables; whilst Spallanzani, and Vauquelin have confirmed it in the case of the lower animals. The necessity for the presence of air, and its due renewal,—as regards man and the upper classes of animals,—is sufficiently obvious. Not less necessary is a due supply of air to aquatic animals. They can be readily drowned, when the air in the water is consumed, if prevented from coming to the surface: if the fluid be put under the receiver of an air-pump, and the air be withdrawn, or if the vessel be placed so that the air cannot be renewed, the same changes are found to have been produced in the air; and hence the necessity of making holes through the ice, where small fish-ponds are frozen over, if we are desirous of preserving the fish alive.

The necessity for the renewal of air is not, however, alike imperative in all animals. Whilst the mammalia, birds, fishes, &c. will speedily expire, when placed under the receiver of an air-pump, if the air be exhausted, the frog is but slightly incommoded. It swells up, almost to bursting, but retains its position, and when the air is admitted, seems to have sustained no injury. This exception, afforded by the amphibious animal to the ordinary effects of destructive agents, we have already had occasion to refer to more than

once; and it is strikingly exemplified in the fact, now indisputable, that the toad has been found alive in the substance of trees and rocks, where no access of air appeared practicable.

The influence of air on mankind is most interesting and important in its hygienic relations, and has accordingly been a topic of study since the days of Hippocrates. In another work, it has been investigated, at considerable length, by the author.*

Physiology of Respiration.

Within certain limits, the function of respiration is under the influence of volition. The muscles, belonging to it, have consequently been termed *mixed*, as we can at pleasure increase or diminish their action, but cannot arrest it altogether, or for any great length of time. If, by a forced inspiration, we take air into the chest in large quantity, we find it impossible to keep the chest in this condition beyond a certain time. Expiration irresistibly succeeds, and the chest resumes its pristine situation. The same occurs if we expel the air as much as possible from the lungs. The expiratory effort cannot be prolonged indefinitely, and the chest expands in spite of the effort of the will.

These facts have given rise to two curious and deeply interesting topics of inquiry;—the cause of the first inspiration in the new-born infant? and of the regular alternation of inspiration and expiration during the remainder of existence? The first of these questions will fall under consideration, when we investigate the physiology of infancy; the latter will claim some attention at present.

Haller attempted to account for the phenomenon by the passage of the blood through the lungs being impeded during expiration,—a reflux of blood into the veins, and a degree of pressure upon the brain being thus induced. Hence, a painful sense of suffocation arises, in consequence of which the muscles of inspiration are called into action by the will, for the purpose of enlarging the chest, and, in this way, removing the impediment. The same uneasy feelings, however, ensue from inspiration, if too long protracted: the muscles cease to act, and, by their relaxation, the opposite state of the chest is induced. Whytt conceived, that the passage of the blood through the pulmonary vessels is impeded by expiration, and that a sense of anxiety is thus produced. This unpleasant sensation acts as a stimulus upon the nerves of the lungs and the parts connected with them, which arouses the energy of the sentient principle; and this, by causing contraction of the diaphragm, enlarges the chest, and removes the painful feeling. The muscles then cease to act, in consequence of the stimulus no longer existing.

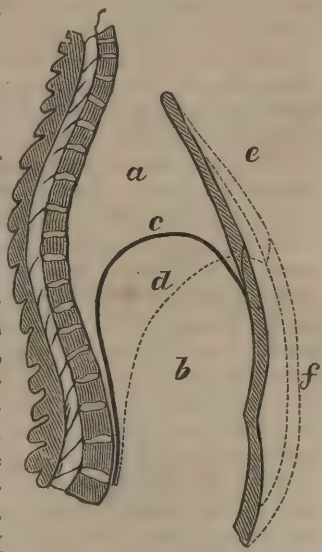
These, and all other methods of accounting for the phenomena, are, however, too pathological. From the first moment of respira-

* 'On the influence of atmosphere and locality, &c. &c., on human health, constituting elements of hygiene,' pp. 33 to 305.

tion the process appears to be accomplished without the slightest difficulty, and to be as much a part of the instinctive extra-uterine actions of the frame, as circulation, digestion, or absorption. It is obviously an internal sensation, after respiration has been once established; and, like all internal sensations, is inexplicable in our existing state of knowledge. The part, which developes the impression, is probably the lung, through its ganglionic nerves; the pneumogastric nerves convey the impression to the brain; and the brain calls into action the muscles of inspiration. We say, that the action of impression arises in the lungs, and this, from some internal cause, connected with the office it has to fill in the economy; but in so saying we sufficiently exhibit our total want of acquaintance with its nature.

Let us now inquire into the movements of *inspiration* and *expiration*, which, together, constitute the function of respiration. These acts are entirely accomplished by the dilatation and contraction of the thorax. The air enters the chest when the latter is expanded; and it is driven out, when the chest is restored to its ordinary dimensions;—the thorax thus seeming to act like an ordinary pair of bellows with the valve stopped; when the sides are separated, the air enters at the nozzle, and is forced out, when they are brought together.

Fig. 118.



Section of the thorax and abdomen.

a. The thorax.—*b*. The abdomen.—*c*. The relaxed diaphragm.

Inspiration.—The augmentation of the capacity of the thorax, which constitutes inspiration, may be effected to a greater or less extent, according to the number of muscles which are thrown into action. The chest may, for example, be dilated by the diaphragm alone. This muscle, as we have seen, in its ordinary relaxed condition, is convex towards the chest, as in the marginal figure, and in Fig. 119. When, however, it contracts, it becomes more horizontal; and assumes the position indicated by the dotted line *d*, Fig. 118. in this manner augmenting the cavity of the chest in a vertical direction. The sides or lateral portions of the diaphragm, which are fleshy and correspond to the lungs, descend more, in this movement, than the central tendinous portion, which is moreover kept immovable by its attachment to the sternum, and its union with the pericardium. In the gentlest of all breathing, the diaphragm appears to be the sole agent of inspiration; and, in cases of inflammation of the pleura costalis, or of fractured rib, our en-

deavours are directed to the prevention of any elevation of the ribs by which the diseased part can be put upon the stretch. Generally, however, as the diaphragm descends, the viscera of the abdomen are compressed; the abdominal muscles assume the position of the double dotted line *f*, and the ribs and the breast bone are raised so that the latter is protruded as far as the dotted line *e*.

When the diaphragm acts, and, in addition, the ribs and sternum are raised, the cavity of the chest is still farther augmented.

The mechanism, by which the ribs are raised, has been productive of more controversy than the subject merits. Haller asserted, that the first rib is immovable, or at least admits of but trifling motion when compared with the others; and he denies, that the thorax makes any movement, as a whole, of either elevation or depression; affirming, that the ribs are raised successively towards the top of the cavity; and this to a greater extent as they are more distant from the first. Magendie, on the other hand, denies that they are elevated in this manner; and endeavours to show, that they are all raised at the same time; that the first rib instead of being the least movable is the most so; and that the disadvantage, which the lower ribs possess in the movement, by their admitting of less motion in their posterior articulations, is compensated by the greater length of these ribs. This compensation he considers to have its advantages; for as the true ribs, with their cartilages and the sternum, usually move together, and the motion of one of these parts almost always induces that of the rest, it would follow, that if the lower ribs were more movable, they could not execute a more extensive movement than they do; whilst the solidity of the thorax would be diminished. They, who are desirous of seeing this question canvassed, will find it in the third volume of the *Elementa Physiologiæ* of Haller, and in the *Précis* of Magendie. By the elevation, then, of the ribs, and the depression of the diaphragm, the chest is augmented, and a deeper inspiration effected than when the diaphragm acts singly. In this elevation of the ribs, we see the advantage of their obliquity as regards the spine. Had they been horizontal, or inclined obliquely upwards, any elevation would necessarily have contracted the thoracic cavity, and favoured expiration instead of inspiration

The muscles, chiefly concerned in inspiration, are the intercostals, and those muscles, which arise, either directly or indirectly, from the spine, head, or upper extremities, and which can, in any manner, elevate the thorax. Amongst these, are the scaleni antici and postici, the levatores costarum, the muscles of the neck, which are attached to the sternum, &c.

As no air exists in the cavity of the pleura, it necessarily happens, that, when the capacity of the chest is augmented, the residuary air, contained in the air-cells of the lungs after expiration, is rarefied; and, in consequence, the denser air without enters the larynx by the mouth and nose, until the air within the lungs has attained the density, which the residuary air had prior to inspiration,

—not that of the external air, as Sir Charles Bell has affirmed. At the time of inspiration, the glottis opens by the relaxation of the arytenoidei muscles, as Legallois proved by experiments, performed at the *Ecole de Médecine* of Paris. On exposing the glottis of a living animal, the aperture is found to dilate very distinctly at each inspiration, and to contract at each expiration. If the eighth pair of nerves be devided low down in the neck, and the dilator muscles of the glottis, which receive their nerves from the recurrents—branches of the eighth pair—be thus paralyzed, the aperture is no longer enlarged during inspiration, whilst the constrictors—the arytenoidei muscles—which receive their nerves from the superior laryngeal,—given off above the point of section—preserve their action, and close the glottis more or less completely.

When the air is inspired through the mouth, the velum is raised, so as to allow the air to pass freely to the glottis; and, in forced inspiration, it is so horizontal, as to completely expose the pharynx to view. The physician takes advantage of this, in examining morbid affections of those parts, and can often succeed much better in this way than by pressing down the tongue. On the other hand, when inspiration is effected entirely through the nose, the velum palati is depressed, until it becomes vertical, and no obstacle exists to the free entrance of the air into the larynx. In such case, where difficulty of breathing exists, the small muscles of the alæ nasi are frequently thrown into violent action, alternately dilating and contracting the apertures of the nostrils; and hence this is a common symptom in pulmonary affections.

Mayow conceived, that the air enters the lungs in inspiration as it would a bladder put into a pair of bellows, and communicating with the external air by the pipe of the instrument. The lungs, however, are not probably so passive as this view would indicate. In cases of hernia of the lungs, the extruded portion has been observed to dilate and contract in inspiration and expiration. Reisseisen believed this to be owing to muscular fibres, which Meckel and himself conceived to perform the whole circuit of the bronchial ramifications. These are not, however, generally admitted by anatomists, and the phenomenon is usually ascribed to the bronchi having in their composition the highly elastic tissue, which is an important constituent of the arteries. Laennec affirms, that he has endeavoured, without success, to verify the observations of Reisseisen; but that the manifest existence of circular fibres on branches of a moderate size, and the phenomena, presented by many kinds of asthma, induce him to consider the temporary constriction and occlusion of the minute bronchial ramifications as a thing well established. In the trachea, an obvious muscular structure exists in its posterior third, where the cartilages are wanting. There it consists of a thin muscular plane, the fibres of which pass transversely between the interrupted extremities of the cartilaginous rings of the trachea and bronchi. The use of this muscular tissue, as suggested by Dr. Physick, and, since him, by Cruveilhier and Sir Charles Bell,

is, to diminish the calibre of the air tubes in expectoration; so that the air having to pass through the contracted portion with greater velocity, its momentum may remove the secretions that are adherent to the mucous membrane. The explanation is ingenious and probably just.

Magendie asserts, that the lung has a constant tendency to return upon itself, and to occupy a smaller space than that which it fills; and, that it consequently exerts a degree of traction on every part of the parietes of the thorax. This traction has but little effect upon the ribs, which cannot yield; but upon the diaphragm it is considerable. It is, indeed, in his opinion, the cause, why that muscle is always tense, and drawn so as to be vaulted upwards; and when the muscle is depressed during contraction, it is compelled to draw down the lungs towards the base of the chest, so that they are stretched, and, by virtue of their elasticity, have a more powerful tendency to return upon themselves, and to draw the diaphragm upwards. If a puncture be made into the chest in one of the intercostal spaces, the air will enter the chest through the aperture, and the lung will shrink. By this experiment, the atmospheric pressure is equalized on both surfaces of the lung, and the organ assumes a bulk determined by its elasticity and weight. Owing to this resiliency of the lungs, and to their consequent tendency to recede from the pleura costalis, there is less pressure upon all the parts against which the lungs are applied; and, accordingly, the heart is not exposed to the same degree of pressure as the parts external to the chest; and the degree of pressure is still farther reduced, when the chest is fully dilated, the lungs farther expanded, and their elastic resiliency increased.

Many physiologists have pointed out three degrees of inspiration, but it is manifest, that there may be innumerable shades between them:—1. *Ordinary gentle inspiration*, which is owing simply to the action of the diaphragm; or, in addition, to a slight elevation of the chest. 2. *Deep inspiration*, where, with the depression or contraction of the diaphragm, there is evident elevation of the thorax; and, lastly, *forced inspiration*, when the air is strongly drawn in, by the rapid dilatation, produced by the action of all the respiratory muscles that elevate the chest directly or indirectly.

Many trials have been instituted for determining the quantity of air, taken into the lungs at an inspiration; and considerable diversity, as might be expected, exists in the evaluations of different experimenters. We have just remarked, that, in the same individual, the inspiration may be gentle, deep, or forced; and, in each case, the quantity of air inspired will necessarily differ. There is, likewise, considerable diversity in individuals, as regards the size of the chest; so that an approximation can alone be attained. The following table sufficiently exhibits the discordance of authors on this point. Many, however, of the estimates, which seem so extremely discrepant, may probably be referred to imperfection in the mode

of conducting the experiment, as well as to the causes abovementioned:—

	Cubic inches at each Inspiration.		Cubic inches at each Inspiration.
Reil, - -	42 to 100	Fontana, - -	35
Menzies,		Richerand, -	30 to 40
Sauvages,		Dalton, - -	30
Hales,		Herholdt, -	20 to 29
Haller,		Jurine, - -	20
Ellis,	40	Allen and Pepys,	16½
Sprengel,		J. Borelli, - -	15 to 40
Sömmering,		Goodwyn, -	14
Thomson,		Sir H. Davy, -	13 to 17
Bostock,		Abernethy, -	12
Jurin, - -	35 to 38	Keutsch, - -	6 to 12

In passing through the mouth, nasal fossæ, pharynx, larynx, trachea, and bronchi, the inspired air acquires pretty nearly the temperature of the body; and, if the air has been cool, the same quantity by weight occupies a much larger space in the lungs, owing to its rarefaction in those organs. In its passage, too, it becomes mixed with the halitus, which is constantly exhaled from the mucous membrane of the air-passages; and, in this condition, it enters the air-cells, and becomes mixed with the residuary air in the lungs after expiration.

Expiration.—An interval, scarcely appreciable, elapses after the accomplishment of inspiration, before the reverse movement of *expiration* succeeds; and the air is expelled from the chest. The great cause of this expulsion is the restoration of the chest to its former dimensions; and the elasticity of the yellow tissue composing the bronchial ramifications, which have been put upon the stretch by the air rushing into them, during inspiration.

The restoration of the chest to its dimensions may be effected simply by the cessation of the contraction of the muscles, that have raised it, and the elasticity of the cartilages, which connect the bony portion of the ribs with the sternum or breast-bone. In active expiration, however, the ribs are depressed by the action of appropriate muscles, and the chest is thus still farther contracted. The chief expiratory muscles are the triangularis sterni, the broad muscles of the abdomen, rectus abdominis, sacro-lumbalis, longissimus dorsi, serratus posticus inferior, &c. Haller conceived that the ribs, in expiration, are successively depressed towards the last rib; which is first fixed by the abdominal muscles and quadratus lumborum. The intercostal muscles then act and draw the ribs successively

downwards. Magendie contests the explanation of Haller; and the truth would seem to be, that the muscles, just mentioned, participate with the intercostals in every expiratory movement.

By this action, the capacity of the chest is diminished; the lungs are correspondently pressed upon, and the air issues by the glottis. It has been already remarked, that, during expiration, the arytenoidei muscles contract, and the glottis appears to close. Still, space sufficient is left to permit the exit of the air.

It has been asked—is the air expired precisely that which has been taken in by the previous inspiration? It is impossible to empty the lungs wholly by the most forced expiration. A portion still remains; and hence it has been assumed, that the use of inspiration is to constantly renew the air remaining in the air-cells. On this subject we are not well informed; but it is probable that the lighter and more rarefied air gives way to the newly-arrived and denser medium; and that, thus, fresh air is continually exposed to the blood of the pulmonary vessels. A multitude of experiments have been made to determine the change of bulk which air experiences by being respired. According to Sir Humphry Davy, it is diminished, by a single inspiration and expiration, from $\frac{1}{70}$th to $\frac{1}{100}$th part of its bulk. Cuvier makes it about $\frac{1}{50}$th; Allen and Pepys a little more than a half per cent. Berthollet from 0.69 to 3.70 per cent; and Bostock $\frac{1}{80}$th, as the average diminution. Assuming this last estimate to be correct, and forty cubic inches to be the quantity of air drawn into the lungs at each inspiration, it will follow, that half a cubic inch disappears each time we respire. This, in a day, would amount to 14,400 cubic inches, or to rather more than eight cubic feet. The experiments of MM. Dulong and Despretz make the diminution considerable. The latter gentleman placed six small rabbits in forty-nine quarts of air for two hours, at the expiration of which time the air had diminished one quart. A portion of the inspired air must consequently have been absorbed.

Attempts have been made to estimate the quantity of air remaining in the lungs after respiration; but the sources of discrepancy are here as numerous as in the cases of inspiration or expiration. Goodwyn estimated it at 109 cubic inches; Menzies at 179; Jurine at 220; Fontana at 40; and Cuvier, after a forced inspiration, at from 100 to 60. Davy concluded, that his lungs, after a forced expiration, still retained 41 cubic inches of air. After a natural expiration they contained - - - 118 cubic inches.
After a natural inspiration, - - - 135
After a forced inspiration, - - - 254
By a full forced expiration after a forced inspiration, he threw out - - - - - - - - 190 cubic inches.
After a natural inspiration, - - - 78.5
After a natural expiration, - - - 67.5

It is impossible, from such variable data, to deduce any thing like a satisfactory conclusion; but if we assume with Bostock, (and Dr. Thomson is disposed to adopt the estimate,) 170 cubic inches

as the quantity, that may be forcibly expelled, and that 120 cubic inches will be still left in the lungs, we shall have 290 cubic inches as the measure of the lungs in their natural or quiescent state; to this quantity, 40 cubic inches are added by each ordinary inspiration, giving 330 cubic inches as the measure of the lungs in their distended state. Hence it would seem, that about one-eighth of the whole contents of the lungs is changed by each respiration; and that rather more than two-thirds can be expelled by a forcible expiration. Supposing, that each act of respiration occupies three seconds, or that we respire twenty times in a minute, a quantity of air, rather more than $2\frac{3}{4}$ times the whole contents of the lungs, will be expelled in a minute, or about four thousand times their bulk in twenty-four hours. The quantity of air, respired during this period, will be 1,152,000 cubic inches, about $666\frac{1}{2}$ cubic feet. Such is Bostock's estimate.

It is the residuary air, that gives to the lungs the property of floating on the surface of water, after they have once received the breath of life, and no pressure, that can be employed, will force out the air, so as to make them sink. Hence, the chief proofs, whether a child has been born alive or dead, are deduced from the lungs. These proofs constitute the *docimasia pulmonum*, or Lungenprobe of the Germans.

Expiration, like inspiration, has been divided into three grades: *ordinary*, *free*, and *forced;* but it must necessarily admit of multitudinous shades of difference. In *ordinary* passive respiration, expiration is effected solely by the relaxation of the diaphragm. In *free* active expiration, the muscles, that raise the ribs, are likewise relaxed, and there is a slight action of the direct expiratory muscles. In *forced* expiration, all the respiratory muscles are thrown into action. In this manner, the air makes its way along the air-passages through the mouth or nostrils or both; carrying with it a fresh portion of the halitus from the mucous membrane. This it deposits, when the atmosphere is colder than the temperature acquired by the respired air, and if the atmosphere be sufficiently cold, as in winter, the vapour becomes condensed as it passes out, and renders expiration visible.

The number of respirations, in a given time, differs considerably in different individuals. Dr. Hales reckons them at twenty. A man, on whom Menzies made experiments, breathed only fourteen times in a minute. Sir Humphry Davy made between twenty-six and twenty-seven in a minute. Dr. Thomson about nineteen, and Magendie fifteen. Our own average, is sixteen. The average, deduced from the few observers, that have recorded their statements, —or twenty per minute,—has generally been taken; but we are satisfied it is above the truth; eighteen would be nearer the general average; and it has, accordingly, been admitted by many. Eighteen in a minute give twenty-five thousand nine hundred and twenty in the twenty-four hours.

The number of respirations is influenced by various circum-

stances. The child and the female breathe more rapidly than the adult male. We find as much variety, too, in him as we do in the horse; whilst some men are short-winded, others are long-winded: and this last condition may be improved by appropriate *training*; to which the pedestrian, and the prize-fighter, equally with the horse, are submitted for some time before they exhibit their powers. In sleep, the respiration is generally deeper, less frequent, and appears to be effected greatly by the intercostals and diaphragm. Motion has also a sensible effect in hurrying the respiration, as well as the distention of the stomach by food, certain mental emotions, &c., and its condition during disease becomes a subject of interesting study to the physician, and one that has been much facilitated by the acoustic method, introduced by Laennec. To his instrument—the *stethoscope*—allusion has already been made. By it or by the ear applied to the chest, we are able to hear distinctly the respiratory murmur and its modifications; and thus to judge of the nature of the pulmonary affection when existent. But this is a topic that appertains to pathology.

There are certain respiratory movements concerned in effecting other functions, which require consideration. Some of these have already been topics of discussion. Adelon has classed them into: *First.* Those employed in the *sense of smell*, either for the purpose of conveying the odorous molecules into the nasal fossæ; or to repel them and prevent their ingress. *Secondly.* The inspiratory action employed in the *digestive function*, as in *sucking*. *Thirdly.* Those connected with muscular motion when forcibly exerted; and particularly in *straining* or the employment of *violent effort*. *Fourthly.* Those concerned in the various *excretions*, either voluntary—as in *defecation* and *spitting*, or involuntary,—as in *coughing*, *sneezing*, *vomiting*, *accouchement*, &c.; and *lastly*, such as constitute phenomena of *expression*—as, *sighing*, *yawning*, *laughing*, *crying*, *sobbing*, &c. Some of these, that have already engaged our attention, do not demand comment; others are topics of considerable interest and require investigation.

Straining. The state of respiration is much effected during the more active voluntary movements. Muscular exertion, of whatever kind, when considerable, is preceded by a long and deep inspiration; the glottis is then closed; the diaphragm and respiratory muscles of the chest are contracted, as well as the abdominal muscles which press upon the contents of the abdomen in all directions. At the same time that the proper respiratory muscles are exerted, those of the face participate, owing to their association through the medium of the respiratory nerves. By this series of actions, the chest is rendered capacious; and the force, that can be developed, is augmented, in consequence of the trunk being rendered immovable as regards its individual parts; and thus serving as a fixed point for the muscles that arise from it, so that they are enabled to employ their full effect.

The physiological state of muscular action, as connected with the mechanical function of respiration, is happily described by Shakspeare, when he makes the 5th Harry encourage his soldiers at the siege of Harfleur:—

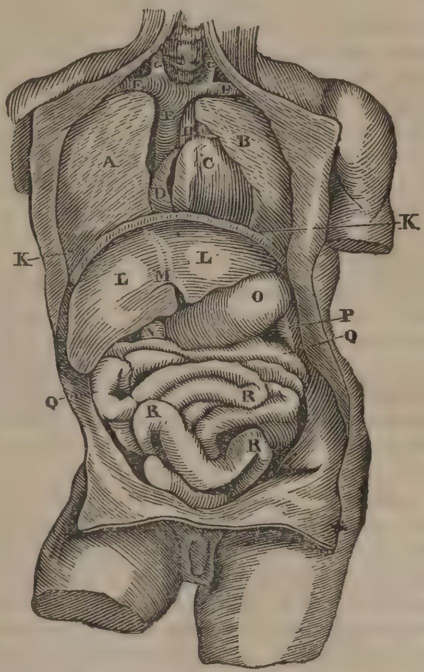
> "Stiffen the sinews, summon up the blood;
> "Now set the teeth, and stretch the nostrils wide;
> "Hold hard the breath and bend up every spirit
> "To his full height."

In the effort required for effecting the various excretions, a similar action of the respiratory muscles takes place. The organs, from which these excretions have to be removed, exist either in the thorax or abdomen; and, in all cases, the organs have to be compressed by the parietes of those cavities. See Fig. 119. A full inspiration is first made; the expiratory muscles, with those that close the glottis, are then forcibly and simultaneously contracted, and by this means the thoracic and abdominal viscera are compressed.

Some difference, however, exists, according as the viscus, to be emptied, is seated in the abdomen or thorax. In the evacuation of the fæces, the lungs are first filled with air; and, whilst the muscles of the larynx contract to close the glottis, those of the abdomen contract also; and as the lung, in consequence of the included air, resists the ascent of the diaphragm, the compression bears upon the large intestine. The same happens in the excretion of the urine and in accouchement.

When the organ, that has to be cleared, is in the thorax,—as in *coughing* to remove mucus from the air-passages,—the same action of the muscles of the

Fig. 119.



Thoracic and abdominal viscera.

A. Right lung.—B. Left lung.—C. Right ventricle of the heart.—D. Right auricle of the heart.—E. Vena cava superior.—F, F Subclavian veins—G, G. Internal jugular veins.—H. Ascending aorta.—I. Pulmonary artery—K. Diaphragm.—L, L. Right and left lobes of the liver.—M. Ligamentum rotundum.—N. Fundus of gall-bladder—O. Stomach.—P. Spleen.—Q, Q. Situation of the kidneys, behind the intestines.—R, R. Small intestines.

abdomen is invoked; but the glottis is open to allow of the exit of the mucus. In this case, the expiratory muscles contract convulsively and forcibly, so that the air is driven violently from the lungs, and, in its passage, sweeps off the irritating matter and conveys it out of the body. To aid this, the muscular fibres, at the posterior part of the trachea and larger bronchial tubes, contract, so as to diminish the calibre of these canals; and, in this way, expectoration is facilitated.

The action differs, however, according as the expired air is sent through the nose or mouth; in the former case, constituting *sneezing;* in the latter, *coughing.* The former is more violent than the latter, and is involuntary; whilst the latter is not necessarily so. In both cases the movement is excited by some external irritant, applied directly to the mucous membrane of the windpipe or nose; or by some modified action in the very tissue of the part, which acts as an irritating cause. In both cases the air is driven forcibly forward, and both are accompanied by sounds that cannot be mistaken. In these actions, we have striking exemplifications of the extensive association of muscles, through the system of respiratory nerves, to which we have so often alluded. The pathologist, too, has repeated opportunities for observing the extensive sympathy between distant parts of the frame, as indicated by the actions of sneezing and coughing, especially of the former. If a person be exposed for a short period to the partial and irregular application of cold, so that the capillary action of a part of the body is modified, as where we get the feet wet, or sit in a draught of air, a few minutes will frequently be sufficient to exhibit sympathetic irritation in the Schneiderian membrane of the nose, and sneezing. Nor is it necessary, that the capillary action of a distant part shall be modified by the application of cold. We have had the most positive evidence, that if the capillary circulation be irregularly excited, even by the application of heat, whilst the rest of the body is receiving none of its influence, inflammation of the mucous membrane of the nasal fossæ and fauces follows with no less certainty.

Blowing the Nose.—The substance, that has to be excreted by this operation, is composed of the nasal mucus, the tears sent down the ductus ad nasum, and the particles deposited on the membrane by the air, in its passage through the nasal fossæ. Commonly, these secretions are only present in quantity sufficient to keep the membrane moist, the remainder being evaporated or absorbed. Frequently, however, they exist in such quantity as to fall by their own gravity into the pharynx, where they are sent down into the stomach by deglutition, are thrown out at the mouth, or make their exit at the anterior nares. To prevent this last effect more especially, we have recourse to blowing the nose. This is accomplished by taking in air, and driving it suddenly and forcibly out, closing the mouth at the same time, so that the air may issue by the nasal fossæ and clear them; the nose being compressed so as to make the velocity of the

air greater, as well as to express all the mucus that may be forced forwards.

Spitting differs somewhat according to the part in which the mucus or matter to be ejected is seated. At times, it is exclusively in the mouth; at others in the back part of the nose, pharynx, or larynx. When the mucus or saliva of the mouth has to be excreted, the muscular parietes of the cavity, as well as the tongue, contract so as to eject it from the mouth; the lips being at times approximated, so as to render the passage narrow, and impel the sputa more strongly forward. The air of expiration may be, at the same time, driven forcibly through the mouth, so as to send the matter to a considerable distance. The practised spitter sometimes astonishes us with the accuracy and power of propulsion of which he is capable. When the matter to be evacuated is in the nose, pharynx, or larynx, it requires to be brought, first of all, into the mouth. If in the posterior nares, the mouth is closed, and the air is drawn in forcibly through the nose, the pharynx being at the same time constricted so as to prevent the substances from passing down into the œsophagus. The pharynx now contracts, from below to above, in an inverse movement from that required in deglutition, and the farther excretion from the mouth is effected in the manner just described.

Where the matters are situated in the air-passages, the action may consist in coughing; or, if higher up, simply in *hawking*. A forcible expiration, unaccompanied by cough, is, indeed, in many cases, sufficient to detach the superfluous mucous secretion from even the bronchial tubes. In hawking, the expired air is forcibly sent forwards, and the parts about the fauces are suddenly contracted so as to diminish the capacity of the tube and propel the matters onwards. The noise is produced by their discordant vibration. Both these modes bear the general name of *expectoration*.

When these secretions are swallowed, they are subjected to the digestive process; a part is taken up, and the remainder rejected; so that they belong to the division of *recremento-excrementitial fluids* of some physiologists.

Lastly, it remains to speak of the expiratory phenomena, that strictly form part of the function of expression, and depict the moral feeling of the individual who gives utterance to them.

Sighing consists of a deep inspiration, by which a large quantity of air is received slowly and gradually into the lungs, to compensate for the deficiency in the due aeration of the blood which precedes it. The most common cause of sighing is mental uneasiness; it also occurs at the approach of sleep, or immediately after waking. In all these cases, the respiratory efforts are executed more imperfectly than under ordinary circumstances: the blood consequently does not circulate through the lungs in due quantity, but accumulates more or less in these organs, and in the right side of the heart; and it is to restore the due balance, that the deep inspiration is now and then established.

Yawning, *oscitancy*, *oscitation*, or *gaping*, is likewise a full, deep, and protracted inspiration, accompanied by a wide separation of the jaws, and followed by a prolonged and sometimes sonorous expiration. Yawning is excited by many of the same causes as sighing. It is not, however, the expression of any depressing passion, but is occasioned by any circumstance that impedes the necessary aeration of the blood; whether this be retardation of the action of the respiratory muscles, or the air being less rich in oxygen. Hence we yawn at the approach of sleep, and immediately after waking. The inspiratory muscles, fatigued from any cause, experience some difficulty in dilating the chest; the lungs are consequently not properly traversed by the blood from the right side of the heart: oxygenation is, therefore, not duly effected; an uneasy sensation is induced, which is put an end to by the action of yawning, which allows the admission of a considerable quantity of air. We yawn at the approach of sleep, because, the agents of respiration, becoming gradually more debilitated, require to be now and then excited to fresh activity, and the blood needs the necessary aeration. Yawning on waking seems to be partly for the purpose of stimulating the respiratory muscles to greater activity, the respiration being always slower and deeper during sleep. It is of course impossible to explain, why the respiratory nerves should be those that are chiefly concerned, under the guidance of the brain, in these respiratory movements of an expressive character. The fact, however, is certain; and it is remarkably proved by the circumstance, that yawning can be excited by even looking at another affected in in this manner; nay, by simply looking at a sketch, and by even thinking of the action. The same also applies to sighing and laughing, and especially to the latter.

Pandiculation or *stretching* is a frequent concomitant of yawning, and appears to be established instinctively to arouse the extensor muscles to a balance of power, when the action of the flexors has been predominant. In sleep, the flexor muscles exercise that preponderance which, in the waking state, is exerted by the extensors. This, in time, is productive of some uneasiness; and, hence, at times during sleep, but still more at the moment of waking, the extensor muscles are roused to action, to restore the equipoise; or, perhaps, as the muscles of the upper extremities, and those concerned, directly or indirectly, in respiration, are chiefly concerned in the action, it is exerted for the purpose of arousing the respiratory muscles to increased activity.

By Dr. Good, yawning and stretching have been regarded as morbid affections and amongst the signs of debility and lassitude:—"Every one," he remarks, "who resigns himself ingloriously to a life of lassitude and indolence will be sure to catch these motions as a part of that general idleness which he covets. And, in this manner, a natural and useful action is converted into a morbid habit; and there are loungers to be found in the world, who, though in the

prime of life, spend their days as well as their nights in a perpetual routine of these convulsive movements over which they have no power; who cannot rise from the sofa without stretching their limbs, nor open their mouths to answer a plain question without gaping in one's face. The disease is here idiopathic and chronic; it may perhaps be cured by a permanent exertion of the will, and ridicule or hard labour will generally be found the best remedies for calling the will into action."

Laughing is a convulsive action of the muscles of respiration and voice, accompanied by a facial expression, which has been explained elsewhere. It consists of a succession of short, sonorous expirations. The air is first inspired so as to fill the lungs. To this succeed short interrupted expirations, with simultaneous contractions of the muscles of the glottis, so that this aperture is slightly contracted, and the lips assume the tension, necessary for the production of sound. The interrupted character of the expirations is caused by convulsive contractions of the diaphragm, which constitute the greatest part of the action. In very violent laughter, the respiratory muscles are thrown into such forcible contractions, that the hands are applied to the sides to support them. The convulsive action of the thorax likewise interferes with the circulation through the lungs; the blood, consequently, stagnates in the upper part of the body; the face becomes flushed; the sweat trickles down the forehead, and the eyes are suffused with tears; but this is apparently owing to mechanical causes; not to the lachrymal gland being excited to unusual action, as in weeping. At times, however, we find the latter cause in operation, also.

The action of *weeping* is very similar to that of laughing; although the causes are so dissimilar. It consists in an inspiration, followed by a succession of short, sonorous expirations. The facial expression, so diametrically opposite to that of laughter, has been depicted in another place.

Laughter and weeping appear to be characteristic of humanity. Animals shed tears, but this does not seem to be accompanied with the mental emotion that characterizes crying in the sense in which we employ the term. It has, indeed, been affirmed by Steller, that the *phoca ursina* or *ursine seal;* by Pallas, that the camel; and by Humboldt, that a small American monkey, shed tears when labouring under distressing emotions. The last scientific traveller states, that "the countenance of the *titi* of the Orinoco,—the *simia sciurea* of Linnæus,—is that of a child;—the same expression of innocence; the same smile; the same rapidity in the transition from joy to sorrow. The Indians affirm, that it weeps like man, when it experiences chagrin; and the remark is accurate. The large eyes of the ape are suffused with tears, when it experiences fear or any acute suffering."

Shakespeare's description of the weeping of the stag,—

> "That from the hunter's aim had ta'en a hurt,"

is doubtless familiar to most of our readers.

> "The wretched animal heav'd forth such groans,
> That their discharge did stretch his leathern coat
> Almost to bursting; and the big round tears
> Cours'd one another down his innocent nose
> In piteous chase; and thus the hairy fool,
> Much marked of the melancholy Jaques,
> Stood on th' extremest verge of the swift brook,
> Augmenting it with tears.

We have less evidence in favour of the laughter of animals. Lecat, indeed, asserts, that he saw the chimpansé both laugh and weep. The ourang-outang, carried to Great Britain, from Batavia, by Dr. Clarke Abel, never laughed; but he was seen occasionally to weep.

Sobbing still more resembles laughing, except that, like weeping, it is usually indicative of the depressing passions; and generally accompanies weeping. It consists of a convulsive action of the diaphragm; which is alternately raised and depressed, but to a greater extent than in laughing and with less rapidity. It is susceptible of various degrees and has the same physical effects upon the circulation as weeping.

Lastly, *panting* or *anhelation* consists in a succession of alternate, quick and short inspirations and expirations. Their physiology, however, does not differ from that of ordinary respiration. The object is, to produce a frequent renewal of air in the lungs, in cases where the circulation is unusually rapid; or where, owing to disease of the thoracic viscera, a more than ordinary supply of fresh air is demanded. We can, hence, understand, why dyspnœa should be one of the concomitants of most of the severe diseases of the chest; and why it should occur whenever the air we breathe does not contain a sufficient quantity of oxygen. The panting, produced by running, is owing to the necessity for keeping the chest as immovable as possible, that the whole effort may be exerted on the muscles of locomotion; and thus suspending, for a time, the respiration, or admitting only of its imperfect accomplishment. This induces an accumulation of blood in the lungs and right side of the heart; and panting is the consequence of the augmented action necessary for transmitting it through the vessels.

Having studied the mode, in which air is received into, and expelled from, the lungs, we have now to inquire into the changes produced on the venous blood—containing the products of the various absorptions—in the lungs, as well as on the air itself. These changes are effected by the function of *sanguification*, *hæmatosis*,

respiration—in the restricted sense, in which it is employed by some —*arterialization* of the blood, *aeration*, *atmospherization*, &c.

With the ancients this process was but little understood. It was generally believed to act as a means of cooling the body; and, in modern times, Helvetius revived the notion, attributing to it the office of refrigerating the blood,—heated by its passage through the long and narrow channels of the circulation,—by the cool air constantly received into the lungs. The reasons, that led to this opinion, were:—that the air, which enters the lungs in a cool state, issues warm; and that the pulmonary veins, which convey the blood from the lungs, are of less dimension than the pulmonary artery, which conveys it to them. From this it was concluded, that the blood, during its progress through the lungs, must lose somewhat of its volume or be condensed by refrigeration. The warmth of the expired air can, however, be readily accounted for; whilst it is not true that the pulmonary veins are smaller than the pulmonary artery. The reverse is, indeed, the fact; and it is equally obvious, that the doctrine of Helvetius does not explain how we can exist in a temperature superior to our own: this ought, in his hypothesis, to be impracticable.

Another theory, which prevailed for some time, was;—that during inspiration, the vessels of the lungs are unfolded, as it were; and that thus the passage of the blood from the right side of the heart to the left, through the lungs, is facilitated. Its progress was, indeed, conceived to be impossible during expiration, in consequence of the considerable flexures of the pulmonary vessels. The discovery of the circulation of the blood gave rise to this theory; and Haller attaches considerable importance to it, when taken in connexion with the changes effected upon the blood in the vessels. It is inaccurate, however, to suppose, that the circulation of the blood through the lungs is mechanically interrupted, when respiration is arrested. The experiments of Williams and Kay have shown, that the interruption is owing to the non-conversion of venous into arterial blood, and to the non-adaptation of the radicles of the pulmonary veins for anything but arterial blood, owing to which causes stagnation of blood supervenes in the pulmonary radicles.* Numerous other objections might be made to this view. In the first place, it supposes, that the lungs are emptied at each expiration; and, again, if a simple deploying or unfolding of the vessels were all that is required, any gas ought to be sufficient for respiration,—which is not the fact.

In these different theories, the principal object of respiration is overlooked—the conversion of the venous blood and its various absorptions, conveyed to the lungs by the pulmonary artery, into arterial blood. This is effected by the contact of the inspired air with

* See the article 'Asphyxia,' by the Author, in the 'American Cyclopedia of Practical Medicine and Surgery.'

the venous blood; in which they both lose certain elements, and gain others. Most physiologists have considered that the whole function of hæmatosis is effected in the lungs. Chaussier, however, has presumed, that the air, in passing through the cavities of the nose and mouth, and the different bronchial ramifications, experiences some kind of elaboration, by being agitated with the bronchial mucus; similar to what he conceives to be effected on the aliment in its passage from the mouth to the stomach; but his view is conjectural in both one case and the other.

Legallois, again, thought, that hæmatosis commences at the part, where the chyle and lymph are mixed with the venous blood, or in the subclavian veins. This admixture, he conceives, occurs more or less immediately, is aided in the heart, and the conversion is completed in the lungs. To this belief he was led by the circumstance, that when the blood quits the lungs, it is manifestly arterial, and he thought, that what the products of absorption lose or gain in the lungs is too inconsiderable to account for the important and extensive change; and that therefore it must have commenced previously. Facts, however, are not exactly in accordance with the view of Legallois. They seem to show, that the blood of the pulmonary artery is analogous to that of the subclavian veins; and hence it is probable, that there is no other action exerted upon the fluid in this part of the venous system, than a more intimate admixture of the venous blood with the chyle and lymph in their passage through the heart.

The changes, wrought on the air by respiration, are considerable. It is immediately deprived of a portion of one of its constituents—oxygen; and it always contains, when expired, a quantity of carbonic acid greater than it had when received into the lungs, along with an aqueous and albuminous exhalation to a considerable amount.

Oxygen is consumed by the respiration of all animals, from the largest quadruped to the most insignificant insect; and, if we examine the expired air, the deficiency is manifest.

Many attempts have been made to estimate the precise quantity of oxygen consumed during respiration; but the results vary essentially from each other; partly owing to the fact, that the amount of oxygen, consumed by the same animal in different circumstances, is not identical. Menzies was, probably, the first that attempted to ascertain the quantity consumed by a man in a day. According to him, 36 cubic inches are expended in a minute; and, consequently, 51840 in the twenty-four hours, equal to 17496 grains. Lavoisier makes it 46048 cubic inches, or 15541 grains. This was the result of his earlier experiments; and in his last, which he was executing at the time when he fell a victim to the tyranny of Robespierre, he made it 15592.5 grains; corresponding largely with the results of his earlier observations. The experiments of Sir Humphry Davy coincide greatly with those of Lavoisier. He found the quantity

consumed in a minute, to be 31.6 cubic inches; making 45504 cubic inches, or 15337 grains in twenty-four hours. The result obtained by Messrs. Allen and Pepys is much less. They consider the average consumption to be, in the twenty-four hours, under ordinary circumstances, 39534 cubic inches, equal to 13343 grains. Now, if we regard the experiments of Lavoisier and Davy, between which there is the greatest coincidence, to be an approximation to the truth, it will follow, that in a day, a man consumes rather more than 25 cubic feet of oxygen; and as the oxygen amounts to only about one-fifth of the respired air, he must render 125 cubic feet of air unfit for supporting combustion and respiration.

The experiments of Crawford, Jurine, Lavoisier and Séguin, Prout, Fyfe, and Edwards, have proved, that the quantity of oxygen consumed varies according to the condition of the functions and of the system generally. Séguin found, that muscular exertion increases it nearly fourfold. Prout, who gave much attention to the subject, was induced to conclude, from his experiments, that moderate exercise increases the consumption; but if the exercise be continued so as to induce fatigue, a diminished consumption takes place. The exhilarating passions also appeared to increase the quantity; whilst the depressing passions and sleep, the use of alcohol and tea, diminished it. He discovered, also, that the quantity of oxygen consumed is not uniformly the same during the twenty-four hours. Its maximum occurred between 10 A. M. and 2 P. M., or generally between 11 A. M. and 1 P. M.; its minimum commenced about 8½ P. M., and it continued nearly uniform till about 3½ A. M.

Dr. Fyfe found, that the quantity was likewise diminished by a course of nitric acid, by a vegetable diet, and by affecting the system with mercury.

Temperature, also, has an effect upon the consumption. Crawford found, that a Guinea-pig, confined in air at the temperature of 55°, consumed double the quantity which it did in air at 104°. He also observed, in such cases, that the venous blood, when the body was exposed to a high temperature, had not its usual dark colour; but, by its florid hue, indicated that little change had taken place in its constitution, in the course of circulation.

We may thus understand the great lassitude and yawning, induced by the hot weather of summer; and the languor and listlessness, which are so characteristic of those who have long resided in torrid climes. Dr. Prout conceives, that the presence or absence of the sun alone regulates the variation in the consumption of oxygen which he has described; but the deduction of Dr. Fleming appears to us more legitimate,—that it keeps pace with the degree of muscular action, and is dependent upon it. Consequently, a state of increased consumption is always followed by an equally great decrease, in the same manner as activity is followed by fatigue.

The disagreement of experimenters, as respects the removal of *nitrogen* or *azote* from the air, during respiration, is still greater than

in the case of oxygen. Priestley, Davy, Humboldt, Henderson, Cuvier, Pfaff, and Thomson, found a less quantity exhaled than was inspired. Spallanzani, Lavoisier and Séguin, Vauquelin, Allen and Pepys, Ellis, and Dalton, inferred, that neither absorption nor exhalation takes place,—the quantity of that gas undergoing no change during its passage through the air-cells of the lungs; whilst Jurine, Nysten, Berthollet, and Dulong and Despretz, on the contrary, found an increase in the bulk of the azote. In this uncertainty, most physiologists have been of opinion, that the azote is entirely passive in the function. The facts, ascertained by Dr. W. F. Edwards, of Paris, shed considerable light on the causes of this discrepancy amongst observers. He has satisfactorily shown, that, during the respiration of the same animal, the quantity of azote may, at one time, be augmented, at another diminished, and, at a third, wholly unchanged. These phenomena he has traced to the influence of the seasons, and he suspects that other causes have a share in their production. In nearly all the lower animals that were the subjects of experiment, an augmentation of azote was observable during summer. Sometimes, indeed, it was so slight that it might be disregarded; but, in numerous other instances, it was so great as to place the fact beyond the possibility of doubt; and, on some occasions, it almost equalled the whole bulk of the animal. Such were the results of his observations until the close of October, when he noticed a sensible diminution in the nitrogen of the inspired air, and the same continued throughout the whole of winter and the beginning of spring. Dr. Edwards considers it probable, that, in all cases, both exhalation and absorption of azote are going on; that they are frequently accurately balanced, so as to exhibit neither excess nor deficiency of azote in the expired air, whilst, in other cases, depending, as it would appear, chiefly upon temperature, either the absorption or the exhalation is in excess, producing a corresponding effect upon the composition of the air of expiration.

But, not only has the respired air lost its oxygenous portion, it has gained, as we have remarked, an accession of *carbonic acid*, and, likewise, a quantity of serous vapour. If we breathe through a tube, one end of which is inserted into a vessel of lime-water, the fluid soon becomes milky, owing to the formation of carbonate of lime, which is insoluble in water. Carbonic acid must consequently have been given off from the lungs.

In the case of this gas, again, the quantity, formed in the day, has been attempted to be computed. Jurine conceived, that the amount, in air once respired in natural respiration, is in the enormous proportion of $\frac{1}{10}$th or $\frac{1}{12}$th. Menzies, that it is $\frac{1}{20}$th; and, from his estimate of the total quantity of air respired in the twenty-four hours, he deduced the amount of carbonic acid formed to be 51840 cubic inches, equal to 24105.6 grains. Lavoisier and Séguin, in their first experiments, valued it at 17720.89 grains; but, in the very next year, they reduced their estimate more than one-half;—to 8450.20

grains; and, in Lavosier's last experiment, it was farther reduced to 7550.4 grains. Sir Humphry Davy's estimate nearly corresponds with that of the first experiment of Lavoisier and Séguin,—17811.36 grains; and Messrs. Allen and Pepys accord pretty nearly with him. These gentlemen found, that atmospheric air, when inspired, issued on the succeeding expiration, charged with from 8 to 6 per cent. of carbonic acid gas; but this estimate exceeds considerably that of Dr. Apjohn, of Dublin, who, in his experiments, found the expired air to contain only 3.6 per cent. of this gas. The experiments and observations of Crawford, Prout, Edwards, and others, to which we have referred—as regards the consumption of oxygen, under various circumstances—apply equally to the quantity of carbonic acid formed, which always bears a pretty close proportion to the oxygen consumed. These experiments also account, in some degree, for the descrepancy in the statements of different individuals on this subject.

It has been a question, amongst physiologists, whether the quantity of carbonic acid gas given out is equal in bulk to the oxygen taken in. In Priestley's experiments, the latter had the preponderance. Menzies and Crawford found them to be equal. Lavoisier and Séguin supposed the oxygen, consumed in the twenty-four hours, to be 15661.66 grains; whilst the oxygen, required for the formation of the carbonic acid given out, was no more than 12924 grains; and Sir Humphry Davy, in the same time, found the oxygen consumed to be 15337 grains, whilst the carbonic acid produced was 17811.36 grains; which would contain 12824.18 grains of oxygen. The experiments of Allen and Pepys, seem, however, to show, that the oxygen which disappears is replaced by an equal volume of carbonic acid; and hence, it was supposed, that the whole of it must have been employed in the formation of this acid. They, consequently, accord with Menzies and Crawford; and the view is embraced by Dalton, Prout, Ellis, Henry, and other distinguished individuals. On the other hand, the view of those, who consider that the quantity of carbonic acid produced is less than that of the oxygen which has disappeared, is embraced by Thomson, and by Dulong and Despretz. In the carnivorous animal, they found the difference as much as one-third; in the herbivorous, on the average, only $\frac{1}{10}$th.

The more recent experiments of Dr. Edwards have shown, that here, also, the discordance has not depended so much upon the different methods and skill of the operators, as upon a variation in the results arising from other causes; and he concludes, that the proportion of oxygen consumed, to that employed in the production of carbonic acid, varies from more than one-third of the volume of carbonic acid to almost nothing; that the variation depends upon the particular animal species, subjected to experiment; upon its age, or on some peculiarity of constitution, and that it differs considerably in the same individual at different times.

It would appear, then, that the whole of the oxygen, which re-

spiration abstracts from the air, is not accounted for, in all cases, by the quantity of carbonic acid formed; and that, consequently, a portion of it disappears altogether. It has been supposed, by some, that a part of the watery vapours, given off during expiration, is occasioned by the union of a portion of the oxygen of the air with hydrogen from the blood in the lungs; by others, that the oxygen is absorbed into the blood, and lost in its course through the system, &c.; but these views are entirely conjectural. With regard to the quantity of vapour, combined with the expired air, it will be the subject of inquiry under the head of SECRETION.

The air likewise loses, during inspiration, certain foreign matters that may be diffused in it. In this way, medicines have been attempted to be conveyed into the system. If air, charged with odorous particles,—as with those of turpentine,—be breathed for a short time, their presence in the urine will be detected; and it is probably in this manner that miasmata produce their effects on the frame. All these substances pass immediately through the coats of the pulmonary veins by imbibition, and, in this way, speedily affect the system.

These changes, produced in the air during respiration, are easily shown, by placing an animal under a bell-glass until it dies. On examining the air, it will be found to have lost largely of its oxygen, and to contain much carbonic acid and aqueous vapour.

Let us inquire, then, whether the changes, produced in the respired air, are connected with those effected on the blood in the lungs. In its progress through the lungs, this fluid has been changed from *venous* into *arterial.* It has become of a florid red colour; of a stronger odour; of a higher temperature by nearly two degrees; of less specific gravity, and it coagulates more speedily. That this conversion is owing to the contact of air in the lungs we have many proofs. Lower was one of the first, who clearly pointed out, that the change of colour occurs in the capillaries of the lungs. Prior to his time, the most confused notions had prevailed on the subject, and the most visionary hypotheses had been indulged. On opening the thorax of a living animal, he observed the precise point of the circulation at which the change of colour takes place, and he showed, that it is not in the heart, since the blood continues to be purple, when it leaves the right ventricle. He then kept the lungs artificially distended, first with a regular supply of fresh air, and afterwards with the same portion of air without renewing it. In the former case, the blood experienced the usual change of colour. In the second, it was returned to the left side of the heart unchanged.

Experiments, more or less resembling those of Lower, have been performed by Goodwyn, Cigna, Bichat, Wilson Philip, and numerous others, with similar results.

The direct experiments of Priestley more clearly showed, that the change, effected on the blood, was to be ascribed to the air. He found, that the clot of venous blood, when confined in a small

quantity of air, assumed a scarlet colour, and that the air experienced the same change as by respiration. He afterwards examined the effect produced on the blood by the gaseous elements of the atmosphere separately, as well as by the other gaseous fluids that had been discovered. The clot was reddened more rapidly by oxygen than by the air of the atmosphere, whilst it was reduced to dark purple by nitrogen, hydrogen, and carbonic acid.

Since Priestley's time, the effect of different gases on the colour of venous blood has been investigated by numerous individuals. The following is the result of their observations, as given by Thénard. It must be remarked, however, that all the experiments have been made on blood, when out of the body; and it by no means follows, that precisely the same changes would be accomplished if the fluid were circulating in the vessels.

Gas.	Colour.	Remarks.
Oxygen - - - -	Rose red.	The blood employed had been beaten, and, consequently, deprived of its fibrine.
Atmospheric air - -	Do.	
Ammonia - - - -	Cherry red.	
Gaseous oxide of carbon	Slightly violet red.	
Deutoxide of azote -	Do.	
Carburetted hydrogen	Do.	
Azote - - - - -	Brown red.	
Carbonic acid - -	Do.	
Hydrogen - - - -	Do.	
Protoxide of azote -	Do.	
Arsenuretted hydrogen Sulphuretted hydrogen	Deep violet, passing gradually to a greenish brown.	
Hydrochloric gas -	Maroon brown.	These three gases coagulate the blood at the same time.
Sulphurous gas - -	Black brown.	
Chlorine - - - -	Blackish b'wn, passing by degrees to a yellowish white.	

It is sufficiently manifest, then, from the disappearance of a part of the oxygen from the inspired air, and from the effects of that gas on venous blood out of the body, that it forms an essential part in the function of sanguification. But we have seen, that the expired air contains an unusual proportion of carbonic acid. Hence carbon, either in its simple state or united with oxygen, must have been given off from the blood in the vessels of the lungs.

To account for these changes on chymical principles has been a great object with chymical physiologists at all times. Priestley supposed the conversion of venous into arterial blood to be a kind of

combustion; and, according to the notion of combustion then prevalent, it was presumed to consist in the disengagement of phlogiston; in other words, the abstraction or addition of a portion of phlogiston made the blood, he conceived, arterial or venous; and the removal of phlogiston he looked upon as the principal use of respiration. This view was modified by Lavoisier, who conceived that both carbon and hydrogen are given off from the lungs, and that they unite with the oxygen of the air by a kind of combustion; a part of the oxygen uniting with the carbon, and forming carbonic acid, another portion uniting with the hydrogen and forming water. The presence of hydrogen was, however, found to be entirely ideal; and, subsequently, the general opinion was, that the most important change experienced by the blood in respiration consists in the removal of its carbon.

Two chief chymical hypotheses have been formed to explain the mode in which this carbon is given off. The first is that of Black, Priestley, Lavoisier, and Crawford;—that the oxygen of the inspired air attracts carbon from the venous blood, and that the carbonic acid is generated by their union. The second, which has been supported by Lagrange, Hassenfratz, Edwards, and others,—that the carbonic acid is generated in the course of the circulation and is given off from the venous blood in the lungs, whilst oxygen gas is absorbed.

The former of these views is still maintained by a number of physiologists. It is conceived, that the oxygen, derived from the air, unites with certain parts of the venous blood,—the carbon and the hydrogen,—owing to which union carbonic acid and water are found in the expired air; the venous blood, thus depurated of its carbon and hydrogen, becomes arterialized; and, in consequence of these various combinations, heat enough is disengaged to keep the body always at the due temperature. According to this theory, as we have seen in the views of Priestley, Lavoisier, &c. respiration is assimilated to combustion.

The resemblance, indeed, between the two processes is, at first sight, considerable. The presence of air is absolutely necessary for respiration; in every variety of respiration the air is robbed of its oxygen; and hence a fresh supply is continually needed; and respiration is always arrested before the whole of the oxygen of the air is exhausted, and this partly on account of the carbonic acid gas given off during expiration. Lastly, it can be continued much longer when an animal is confined in pure oxygen gas than in atmospheric air.

All these circumstances likewise prevail in combustion. Every kind of combustion requires the presence of air. A part of the oxygen of the air is consumed; and, unless the air be renewed, combustion is impossible. It is arrested, too, before the whole of the oxygen is consumed, owing to the carbonic acid formed; and it can be longer maintained in pure oxygen than in atmospheric air.

Moreover, when the air has been respired, it becomes unfit for combustion,—and conversely. Again, the oxygen of the air, in which combustion is taking place, combines with the carbon and hydrogen of the burning body; hence the formation of carbonic acid and water; and as, in this combination, the oxygen passes from the state of a very rare gas, or one containing a considerable quantity of caloric between its molecules, to the condition of a much denser gas, or even of a liquid, the whole of the caloric, which the oxygen contained in its former state, can no longer be held in the latter, and it is accordingly disengaged; hence the heat, which is given off. In like manner, in respiration, the oxygen of the inspired air combines with the carbon and hydrogen of the venous blood giving rise to the formation of carbonic acid and water; and, as in these combinations, the oxygen passes, also, from the state of a very rare to that of a denser gas, or of a liquid, there is a considerable disengagement of caloric, which becomes the source of the high temperature maintained by the human body.

M. Thénard admits a modification of this view,—sanguification being owing, he conceives, to the combustion of the carbonaceous parts of the venous blood, and probably of its colouring matter, by the oxygen of the air.

This chemical theory, which originated chiefly with Lavoisier, and La Place and Séguin, was adopted by Crawford, Gren, Girtanner, and others, with but little modification. Of these modifications it may be well to refer to one or two. Crawford was of opinion, that venous blood contains a peculiar compound of carbon and hydrogen, called *hydro-carbon*, the elements of which unite in the lungs with the oxygen of the air, forming water with the one, and carbonic acid with the other; and that the blood, purified in this manner, assumes the scarlet hue, and becomes adapted to the necessities of the economy. It is only necessary to say, that this supposed hydro-carbon is entirely conjectural.

Mr. Ellis imagined, that the carbon is separated from the venous blood by a secretory process; and that, then, coming into direct contact with oxygen, it is converted into carbonic acid. The circumstance that led him to this opinion was his disbelief in the possibility of oxygen being able to act upon the blood through the animal membrane or coat of the vessel in which it is confined. It is obvious, however, that to reach the blood circulating in the lungs, the oxygen must, in all cases, pass through the coats of the pulmonary vessels. These coats, indeed, offer little or no obstacle, and, consequently, there is no necessity for the vital or secretory action suggested by Mr. Ellis. Priestley and Hassenfratz exposed venous blood to atmospheric air and oxygen in a bladder. In all cases, the parts of the blood, in contact with the gases, became of a florid colour. The experiments of Faust and Mitchell are, in this aspect, pregnant with interest. They prove the great facility with which the tissues are penetrated by the gases, and con-

firm the facts developed by the experiments of Priestley, Hassenfratz and others.

The second hypothesis,—that the carbonic acid is generated in the course of the circulation,—was proposed by Lagrange, in consequence of the objection he saw to the former hypothesis—that the lung ought to be consumed by the perpetual disengagement of caloric taking place within it; or, if not so, that its temperature ought, at least, to be superior to that of other parts. He accordingly suggested, that, in the lungs, the oxygen is simply absorbed, passes into the venous blood, circulates with it, and unites, in its course, with the carbon and hydrogen, so as to form carbonic acid and water, which circulate with the blood and are finally exhaled from the lungs. The objection of Lagrange was, however, ingeniously attempted to be obviated by assuming, that arterial blood has a greater capacity for caloric than venous blood, and, consequently, that when the combustion, under the former theory, takes place in the lungs, the disengaged caloric is taken up by, and becomes latent in, the arterial blood, so that no sensible influence can be exerted by it on the lungs, and that it is disengaged in the capillary vessels, when the blood again becomes venous and acquires a less capacity for caloric;—thus giving rise to the phenomenon of animal heat, which will have to be considered hereafter.

The ingenious and apparently accurate experiments of Dr. Edwards prove convincingly, not only that oxygen is absorbed by the pulmonary vessels, but that carbonic acid is exhaled from them. When he confined a small animal in a large quantity of air, and continued the experiment sufficiently long, he found, that the rate of absorption was greater at the commencement than towards the termination of the experiment; whilst at the former period, there was an excess of oxygen present, and at the latter an excess of carbonic acid. This proved to him that the diminution was dependent upon the absorption of oxygen, not of carbonic acid. His experiments, in proof of the exhalation of carbonic acid, ready formed, by the lungs, are decisive. Spallanzani had asserted, that when certain of the lower animals are confined in gases, containing no oxygen, the production of carbonic acid is uninterrupted. Upon the strength of this assertion, Edwards confined frogs in pure hydrogen, for a length of time. The result indicated, that carbonic acid was produced, and, in such quantity as to show, that it could not have been derived from the residual air in the lungs, as it was, in some cases, equal to the bulk of the animal. The same results, although to a less degree, were obtained with fishes and snails,—the animals on which Spallanzani's observations were made. The experiments of Edwards were extended to the mammalia. Kittens, two or three days old, were immersed in hydrogen. They remained in this situation, for nearly twenty minutes, without dying, and on examining the air of the vessel after death, it was found, that they had given off a quantity of carbonic acid greater than could

possibly have been contained in their lungs at the commencement of the experiment.

The conclusion, deduced by Dr. Edwards, from his various experiments, is, "that the carbonic acid expired is an exhalation proceeding wholly or in part from the carbonic acid contained in the mass of blood." Several experiments were subsequently made by M. Collard de Martigny, who substituted azote for hydrogen; and, in all cases, carbonic acid gas was given out in considerable quantity.

These experiments, then, would seem to show, that in the lungs carbonic acid is exhaled, and that oxygen is absorbed; but it is by no means proved, that the latter goes to the formation of the former. They would also seem to prove the existence of carbonic acid in venous blood, respecting which so much dissidence has existed amongst chymists.

Allusion has already been made to the fact, that gelatine is not met with in the blood, and to the idea of Prout, that its formation from albumen must be a *reducing* process. This process, he considers to be one great source of the carbonic acid, which he conceives to exist in venous blood. Gelatine contains three or four per cent. less carbon than albumen: it enters into the structure of every part of the animal frame, and especially of the skin; the skin indeed, contains little else than gelatine. Dr. Prout considers it, therefore, most probable, that a large part of the carbonic acid of venous blood is formed in the skin, and analogous textures. "Indeed," he adds, "we know, that the skin of many animals gives off carbonic acid, and absorbs oxygen;—in other words, performs all the offices of the lungs;—a function of the skin perfectly intelligible, on the supposition, that near the surface of the body, the albuminous portions of the blood are always converted into gelatine." Recent experiments, however, by Gmelin, Tiedemann and Mitscherlich, and by Stromeyer would seem to demonstrate, that the blood does not contain any free carbonic acid gas, but that it holds a certain quantity in a state of combination, which is set free in the lungs, and commingles with the expired air. The views of Gmelin and Tiedemann, and Mitscherlich on this subject, are as follows:—It may be laid down as a truth, that the greater part if not all the properties of secreted fluids are not dependent upon any act of the secreting organs, but are derived from blood, which again must either owe them to the food, or to changes effected in it within the body. These changes are probably accomplished, in part, during the process of digestion, but are doubtless mainly effected in the lungs by the contact of the blood with the air. Now, most of the animal fluids, when exposed to the air generate, by the absorption of oxygen, acetic or lactic acid, and this is aided by an elevated temperature like that of the lungs.

In their theory of respiration, then, the azote of the inspired air is but sparingly absorbed; by far the greater proportion remaining

in the air cells. The oxygen, on the other hand, penetrates the membranes freely, mingles with the blood, combines partly with the carbon and hydrogen of that fluid, and generates carbonic acid and water, which are thrown off with the expired air, whilst the remainder combines with the organic particles of the blood, forming new compounds, of which the acetic and lactic acids are some; these unite with the carbonated alkaline salts of the blood, and set the carbonic acid free, so that it can be thrown off by the lungs. The acetate of soda, thus formed during the passage of the blood through the lungs is deprived of its acetic acid by the several secretions, especially by those of the skin and kidneys, and the soda again combines with the carbonic acid, which, during the circulation of the blood through the body, is formed by the decomposition of its organic elements. Carbonate of soda is thus regenerated and conveyed to the lungs, to be again decomposed by the fresh formation of acids in those organs.

Chaussier and Adelon, again, regard the whole process of hæmatosis as essentially *organic* and *vital*. They think, that an action of selection and elaboration is exerted both as regards the reception of the oxygen and the elimination of the carbonic acid. But their arguments on this point are unsatisfactory, and are negatived by the facility with which oxygen can be imbibed, and with which carbonic acid transudes through animal membranes. In their view, the whole process is effected in the lungs, as soon as the air comes in contact with the vessel containing the venous blood. The imbibition of oxygen they look upon as a case of ordinary absorption; the transudation of carbonic acid as one of exhalation; both of which they conceive to be, in all cases, *vital* actions, and not to be likened to any physical or chymical operation.

Admitting, then, that the oxygen and a portion of nitrogen absolutely enter the pulmonary vessels, of which we appear to have direct proof, are they, it has been asked, separated from the air in the air-cells, and then absorbed; or does the air enter, undecomposed, into the vessels, and then furnish the proportion of each of its constituents necessary for the wants of the system, the excess being rejected? Could it be shown that such a decomposition is actually effected at the point of contact between the pulmonary vessels and the air in the lungs, it would go far to prove the notion of Ellis, and of Chaussier and Adelon, that an action of selection, or of vitality is exerted; but we have no evidence in favour of this. Sir Humphry Davy, indeed, is of opinion, that the whole of the air is absorbed, and that the surplus quantity of each of the constituents is subsequently discharged. In favour of this view, he remarks, that air has the power of acting upon the blood through a stratum of serum, and he thinks, that the undecomposed air must be absorbed before it can arrive at the blood in the vessels. This is extremely probable; for we have already seen, that air disappears during

respiration, and, consequently, it must have been taken into the system.

After all these experiments and reflections, we are, perhaps, scarcely justified in inferring more than with Raspail, that we have but one incontestable result; namely, that, in the act of respiration, the carbon of the blood combines with the oxygen of the atmospheric air, to be exhaled under the form of carbonic acid.

It has been remarked, that when oxygen is applied to venous blood, the latter assumes a florid colour. On what part of the blood, then, does the oxygen act? The general belief is, upon the red globules. The facts we have stated in the description of venous blood, have shown, that these globules appear to consist of a colourless nucleus, surrounded by a coloured envelope; that both of these are devoid of colour, whilst they exist as chyle and lymph; but that, in the lungs, the contact of air changes the envelope to a florid red. Some, indeed, have believed, that both the envelope and its colour are added in the lungs. The coloration of the blood, consequently, seems to be effected in the lungs; but whether this change is of any importance in hæmatosis is doubtful. Several tissues of the body are not supplied with red blood; in many animals, the red colour does not exist; and, in all, it can perhaps only be esteemed an evidence, that the other important changes have been accomplished in the lungs. Recently, the opinion has been revived, that the oxygen of the air acts upon the iron, which Engelhart and Rose have detected in the colouring matter, but how we know not. It is asserted, that if the iron be separated, the rest of the colouring matter, which is of a venous red colour, loses the property of becoming scarlet by the contact of oxygen.

A different view of arterialization has been advanced by Dr. Stevens. According to him, the colouring matter of the blood is naturally very dark; is rendered still darker by acids, and acquires a florid hue from the addition of chloride of sodium, and from the neutral salts of the alkalies generally. The colour of arterial blood is ascribed by him to hæmatosine reddened by the salts contained in the serum; the characters of venous blood to the presumed presence of carbonic acid, which, like other acids, darkens hæmatosine; and the conversion of venous into arterial blood to the influence of the saline matter in the serum being restored by the separation of carbonic acid.

If we take a firm clot of venous blood, cut off a thin slice, and soak it for an hour or two in repeatedly renewed portions of distilled water; in proportion as the serum is washed away, the colour of the clot deepens, and, when scarcely any serum remains, the colour, by reflected light, is quite black. In this state, it may be exposed to the atmosphere, or a current of air may be blown upon it, without any change of tint whatever; whence it would follow, that when a clot of venous blood, moistened with serum, is made florid by the air,

the presence of serum is essential to the phenomenon. The serum is believed, by Dr. Stevens, to contribute to this change by means of its saline matter; for, when a dark clot of blood, which oxygen fails to redden, is immersed in a pure solution of salt, it quickly acquires the crimson tint of arterial blood, and loses it again when the salt is abstracted by soaking in distilled water.

The facts, detailed by Stevens, are confirmed by Mr. Prater, and by Dr. Turner, of the London University. The latter gentleman, assisted by Professor Quain, of the same Institution, performed the following satisfactory experiment. He collected some perfectly florid blood from the femoral artery of a dog; and, on the following day, when a firm coagulum had formed, several thin slices were cut from the clot with a sharp penknife, and the serum was removed from them by distilled water, which had just before been briskly boiled, and allowed to cool in a well-corked bottle. The water was gently poured on these slices, so that while the serum was dissolved, as little as possible of the colouring matter should be lost. After the water had been poured off, and renewed four or five times, occupying in all about an hour, the moist slices were placed in a saucer, at the side of the original clot, and both portions were shown to several medical friends, all of whom unhesitatingly pronounced the unwashed clot to have the perfect appearance of arterial blood, and the washed slices to be as perfectly venous. On restoring one of the slices to the serum, it shortly recovered its florid colour; and another slice, placed in a solution of bicarbonate of soda, instantly acquired a similar tint; yet, as we have seen, the carbonate of soda is considered by Messrs. Gmelin, Tiedemann and Mitscherlich, to exist in *venous* or black blood.

In brightening, in this way, a dark clot by a solution of a salt or a bicarbonate, Dr. Turner found the colour to be often still more florid than that of arterial blood; but the colours were exactly alike when the salt was duly diluted. Dr. Turner remarks, that he is at a loss to draw any other inference from this experiment, than that the florid colour of arterial blood is not due to oxygen, but, as Dr. Stevens affirms, to the saline matter of the serum. The arterial blood, which was used, had been duly oxygenized within the body of the animal, and should not in that state have lost its tint by the mere removal of its serum; and he adds, the change from venous to arterial blood appears, contrary to the received doctrine, to consist of two parts essentially distinct: one is a chemical change, essential to life, accompanied by the absorption of oxygen and the evolution of carbonic acid; the other depends on the saline matter of the blood, which gives a florid tint to the colouring matter after it has been modified by the action of oxygen. "Such," says Dr. Turner, "appears to be a fair inference from the facts above stated; but being drawn from very limited observations, it is offered with diffidence, and requires to be confirmed or modified by future researches." But we are perhaps scarcely justified in infer-

ring from the experiments of Stevens, Turner, and others, more than the fact, that a florid tint is communicated to blood by sea-salt, and by the neutral salts of the alkalies in general, whilst acids render it still darker. The precise changes, that occur during the arterialization of the blood in the lungs, are still unknown; and if we rely on the recent experiments of Gmelin, Tiedemann, and Mitscherlich, venous blood cannot owe its colour to free carbonic acid, because none is to be met with in it; whilst the presence of the carbonates of alkalies, which they invoke, ought to communicate the florid hue to it.

Since Dr. Stevens published his opinions, the subject has been farther investigated by Dr. William Gregory, and by Mr. Irvine. They introduced also portions of clot, freed, by washing, from serum, into vessels containing pure hydrogen, nitrogen, and carbonic acid, placed over mercury. As soon as the strong saline solution came in contact with them, the colour of the clot, in all the true gases, changed from black to bright red, and the same change was found to take place in the Torricellian vacuum. On repeating these experiments with the serum of the blood, and a solution of salt in water of equal strength with the serum, no change took place until atmospheric air, or oxygen gas, was admitted. It therefore appears—as properly inferred by Mr. Egerton A. Jennings, from whom, by the way, we have an interesting 'report on the chemistry of the blood as illustrative of pathology,' in the third volume of the 'Transactions of the Provincial Medical and Surgical Association' (of England)—that though saline matter may be necessary to effect the change of colour from that of venous to that of arterial blood, still, with so dilute a saline solution, as that which exists in serum, the presence of oxygen is likewise necessary.

The slight diminution, if it exists, in the specific gravity of arterial blood, is considered, but we know not on what grounds, to depend on the transpiration, which takes place in the air-cells, and which was formerly thought to be owing to the combustion of oxygen and hydrogen. This will engage us in another place, as well as the changes produced in its capacity for heat, on which several ingenious speculations have been founded, to account for ANIMAL TEMPERATURE. The other changes are at present inexplicable, and can only be understood hereafter by minute chymical analysis, and by an accurate comparison of the two kinds of blood,—venous and arterial.

It is manifest, from the preceding detail, that our knowledge regarding the precise changes effected upon the air and the blood by respiration are by no means definite. We may, however, consider the following points established. In the first place:—the air loses a part of its oxygen, but this loss varies according to numerous circumstances. 2dly, It is found to have acquired carbonic acid, the quantity of which is also variable; but as a general principle it is less than the oxygen consumed. 3dly, The bulk of the air is dimi-

nished; but the extent of this likewise differs. 4thly, Azote is both absorbed and exhaled by the lungs, to a variable amount. 5thly, The blood, when it attains the left side of the heart, has a more florid colour. 6thly, This change appears to be caused by the contact of oxygen. 7thly, The blood in the lungs gets rid of a quantity of carbon united with oxygen; in the form of carbonic acid. 8thly, It absorbs oxygen, and more than is necessary for the carbonic acid formed. 9thly, The blood, as it passes through the lungs, probably both absorbs and exhales azote;—the proportion which these processes bear to each other being extremely variable. 10thly, The air passes directly through the coats of the pulmonary vessels, and certain portions of each of its constituents are discharged or retained, according to circumstances. Lastly, a quantity of aqueous vapour, containing albumen, is discharged from the lungs, but this is a true secretion, and not a consequence of respiration.

A question, again, has arisen, whether any absorption and exhalation of air, and conversion of blood from venous to arterial, takes place in any other part of the body than the lungs. The reasons, urged in favour of the affirmative of this view, are:—that, in the lower classes of animals, the skin is manifestly the organ for the reception of air; that the mucous membrane of the lungs evidently absorbs air, and is simply a prolongation of the skin, resembling it in texture; and, lastly, that when a limited quantity of air has been placed in contact with the skin of a living animal, it has been absorbed and found to have experienced the same changes as are effected in the lungs. Mr. Cruikshank and Mr. Abernethy analyzed air, in which the hand or foot had been confined for a time, and detected in it a considerable quantity of carbonic acid. Jurine, having placed his arm in a cylinder hermetically closed, found, after it had remained there two hours, that oxygen had disappeared, and that 0.08 of carbonic acid had been formed. These results were confirmed by Gattoni. On the other hand, Drs. Priestley, Klapp, and Gordon, could never perceive the least change in the air under such circumstances. Perhaps in these, as in all cases where the respectability of testimony is equal, the positive should be adopted rather than the negative. It is probable, however, that absorption is effected with difficulty; and that the cuticle, as we have elsewhere shown, is placed on the outer surface to obviate the bad effects which would be induced by heterogeneous, gaseous, miasmatic, or other absorption. We have seen that some of the deleterious gases, as sulphuretted hydrogen, are most powerfully penetrant, and, if they could enter the surface of the body with readiness, unfortunate results might supervene. In those parts where the cuticle is extremely delicate, as in the lips, some conversion of the venous blood into arterial may be effected, and this may be a great cause of their florid colour. According to this view, the arterialization of the blood occurs in the lungs chiefly, owing to their formation being so admi-

rably adapted to the purpose, and it is not effected in other parts, because their arrangement is unfavourable for such result.

It remains for us to inquire into the effect produced on the lungs by the cerebral nerves distributed to them,—or rather, into what is the effect of depriving the respiratory organs of their nervous influence from the brain. The only cerebral or encephalic nerves, distributed to them, are the pneumogastric or eighth pair of Willis, which we have seen are sent, as their name imports, to both the lungs and the stomach. The section of these nerves early suggested itself to physiologists, but it is only in recent times that the phenomena resulting from it have been clearly comprehended. The operation appears to have been performed as long ago as the time of Rufus of Ephesus, and was afterwards repeated by Chirac, Bohn, Duverney, Vieussens, Schräder, Valsalva, Morgagni, Haller, and numerous other distinguished physiologists. It is chiefly, however, in very recent times, and especially by the labours of Dupuytren, Dumas, De Blainville, Provençal, Legallois, Magendie, Breschet, Hastings, Broughton, Brodie, and Wilson Philip, that the precise effects upon the respiratory and digestive function have been appreciated.

When these nerves are divided in a living animal, on both sides at once, the animal dies more or less promptly; at times, immediately after their division, but sometimes it lives for a few days; Magendie says never beyond three or four.

The effects produced upon the voice, by the division of the pneumogastric nerves above the origin of the recurrents, have been referred to under another head. Such division, however, does not simply implicate the larynx, but necessarily effects the lungs, as well as the stomach. As regards the larynx, precisely the same result would be produced by dividing the trunk of the pneumogastric above the origin of the recurrents, as by the division of the recurrents themselves: the muscles, whose function it is to dilate the glottis, are paralyzed; and, consequently, during inspiration, no dilatation takes place; whilst the constrictors, which receive their nerves from the superior laryngeal, preserve all their action, and close the glottis, at times so completely, that the animal dies immediately from suffocation. But if the division of these nerves should not induce instant death in this manner, a series of symptoms follows, considerably alike in all cases, which go on until the death of the animal. These phenomena, according to Magendie, are the following:—respiration is, at first, difficult; the inspiratory movements are more extensive and rapid, and the animal's attention appears to be particularly directed to them; the locomotive movements are less frequent, and evidently fatigue; frequently the animal remains entirely at rest; the formation of arterial blood is not prevented at first, but soon, on the second day for instance, the difficulty of breathing augments, and the inspiratory efforts become gradually greater. The arterial blood has now no longer the ver-

milion hue which is proper to it. It is darker than it ought to be. Its temperature falls. Respiration requires the exertion of all the respiratory powers. At length, the arterial blood is almost like the venous, and the arteries contain but little of it; the body gradually becomes cold, and the animal dies. On opening the chest, the air-cells, the bronchi, and frequently even the trachea, are found filled by a frothy fluid, which is sometimes bloody; the substance of the lung is tumid; the divisions and even the trunk of the pulmonary artery are greatly distended with dark, almost black, blood; and extensive effusions of serum and even of blood are found in the parenchyma of the lungs. Experiments have, likewise, shown, that, in proportion as these symptoms appeared, the animals consumed less and less oxygen, and gave off a progressively diminishing amount of carbonic acid.

From the phenomena that occur after the section of these nerves on both sides, it would seem to follow, that the first effect is exerted upon the tissue of the lungs, which, being deprived of the nervous influence they receive from the brain, are no longer capable of exerting their ordinary elasticity or muscularity, whichsoever it may be. Respiration, consequently, becomes difficult; the blood no longer circulates freely through the capillary vessels of the lungs; the consequence of this is, that transudation of its serous portions, and occasionally effusion of blood, owing to rupture of small vessels, takes place, filling the air-cells more or less; until, ultimately, all communication is prevented between the inspired air and the blood-vessels of the lungs, and the conversion of the venous into arterial blood is completely precluded. Death is, then, the inevitable and immediate consequence.

The division of the nerve of one side affects merely the lung of the corresponding side; life can be continued by the action of one lung only. It is, indeed, a matter of astonishment how long some individuals have lived, when the lungs have been almost wholly obstructed. Every morbid anatomist has had repeated opportunities for observing, that, in cases of pulmonary consumption, for a length of time prior to dissolution, the process of respiration must have been wholly carried on by a very small portion of lung.

The experiments of Dr. Wilson Philip and others moreover show, —what has been more than once inculcated,—the great similarity between the nervous and galvanic fluids. When the state of dyspnœa was induced by the divison of the pneumogastric nerves, the galvanic current was passed from one divided extremity to the other, and, in numerous cases, the dyspnœa entirely ceased. The results of these experiments induced him to try the effect of galvanism in cases of asthma. By transmitting its influence from the nape of the neck to the pit of the stomach, he gave decided relief in every one of twenty-two cases, four of which occurred in private practice, and eighteen in the Worcester Infirmary.

There is one other topic, which, although not directly belonging to physiology, has been so much the subject of experiment with physiologists, that it is worthy of observation. We allude to the

Respiration of different Gases.

Experience has sufficiently proved, that no combination of gases, except that which exists in the atmosphere, is adapted for the prolonged existence of animals, or even of plants. Of the other gases, there are some which are entirely irrespirable, producing a spasmodic closure of the glottis, and thus inducing suffocation; others that are negatively deleterious, by depriving the animal of its due supply of oxygen; and others, again, which act on the body in a positively noxious manner.

Soon after the gases were discovered, their effects upon the respiration of animals were tested; but the most accurate and extensive information, which we possess on the subject was afforded by the labours of Beddoes, and his distinguished pupil Sir Humphry Davy.

The gases, which have been chiefly subjected to experiment, are:—*oxygen*, *protoxide of azote*, *hydrogen*, *azote*, *carburetted hydrogen*, *carbonic acid*, *carbonic oxide*, *sulphuretted hydrogen*, *arsenuretted hydrogen*, *ammoniacal gas*, *muriatic acid gas*, *nitrous acid gas*, *nitric oxide*, and *chlorine*.

Oxygen.—This gas, which we have seen to be so essential to respiration, and which has hence acquired the name *vital air*, has been subjected to numerous experiments, and the general result appears to be, a belief that it acts in a positively deleterious manner; and that, although an animal may live in a limited portion of it a considerable time longer than in the same quantity of atmospheric air, its respiration becomes hurried and laborious before the whole is consumed, and it dies, although a fresh animal of the same kind is capable of sustaining life for some time in the residuary air, The belief is not perhaps legitimate. A part, if not the whole, of the dyspnœa and death may be produced by the evolution of carbonic acid, which is unfavourable to animal life; whilst a fresh animal may be enabled to resist its action for a time and take up some of the residuary oxygen.

According to Allen and Pepys, when the same portion of air is repeatedly respired until it can no longer support life, it then contains ten per cent. of carbonic acid; according to Dr. Apjohn, barely eight per cent.

Oxygen is one of the gases, which has been regarded, on very insufficient evidence however, to exert a stimulant effect upon the blood, by which the left side of the heart, to which the blood is returned from the lungs, and the arterial system are excited to action; and it was accordingly respired, at one time, in diseases of

chronic debility—in chlorosis, asthma, paralysis, &c.; but its use has been long abandoned.

Protoxide of Azote.—This gas, which consists of the same constituents as atmospheric air,—oxygen, and azote,—but in different proportions, is possessed of very singular properties. It is the *dephlogisticated nitrous air* of its discoverer Priestley, the *nitrous oxide, protoxide of nitrogen, paradise* or *laughing gas;* the last name having been assigned to it by reason of its properties.

Sir Humphry Davy first showed, that, by breathing a few quarts of this gas from a silken bag for two or three minutes, effects, resembling those produced by drinking intoxicating liquors, are excited; yet it does not produce the same effect on all individuals, as might, indeed, have been expected. It is strange, however, that although the evidence in Sir Humphry Davy's "Researches" was most overwhelming; and although it is annually breathed in the chymical rooms of this country and Great Britain by hundreds of students, and even made the subject of itinerant exhibition, the French chymists assert, that, in all cases in which they have tried it, it has simply produced indisposition. In the very last edition of his Chymistry, Thénard affirms, "*tous ceux à qui je l'ai vu respirer s'en sont trouvés mal,*" and professor Pelletan, in his "*Dictionnaire de Chimie,*" remarks—that "In England, several persons have exhibited a kind of delirious gaiety, to such an extent, that it was necessary to snatch away the bladder which contained the gas; *debility and syncope soon, however, succeeded this primary state of excitement* (!!) In France, in the experiments of Vauquelin and Thénard, vertigo, head-ache and protracted lassitude were alone experienced; and in no case could it be respired more than a few minutes."

The only way of accounting for these results is by the supposition, that these distinguished chymists must have had idiosyncrasies, which caused them to be affected differently from most other individuals, or that the gas was impure, and that the promulgation of the fact of indisposition having succeeded the respiration of the gas in a few cases has deterred others from having recourse to it.

In his "Researches" on this subject, Sir Humphry Davy has given the autographies of several eminent individuals relative to the effects produced on them. Sir Humphry himself breathed four quarts of nitrous oxide from, and into, a silk bag. His first feelings were those of giddiness; but, in less than half a minute, the respiration being continued, they diminished gradually and were succeeded by a sensation, analogous to gentle pressure on all the muscles, attended by a highly pleasurable thrilling, particularly in the chest and extremities. The objects around him became dazzling, and his hearing more acute. Towards the last inspiration, the thrilling increased, the sense of muscular power became greater; and, at last, an irresistible propensity to action was indulged. What followed after this he recollected but indistinctly; but his motions

were various and violent. The effects soon ceased after the respiration of the gas, and, in ten minutes, he had recovered his natural state of mind. The thrilling in the extremities continued longer than the other sensations.

Dr. Robert Southey, the distinguished laureate of England, could not discriminate between the first effects and an apprehension of which he was unable to divest himself. His first definite sensations were, a fulness and dizziness in the head, such as to induce a fear of falling. This was succeeded by an involuntary laugh, but one of a highly pleasurable character, accompanied with a peculiar thrilling in the extremities;—a sensation perfectly new and delightful. For many hours after this experiment, he imagined, that his taste and smell were more acute, and he felt unusually strong and cheerful. In a second experiment, he felt a still superior pleasure; and has poetically remarked, that he supposes the atmosphere of the highest of all possible heavens to be composed of this gas.

Mr. Wedgewood breathed atmospheric air first without knowing it was so. He declared it to have no effect, which confirmed him in his disbelief of the power of the gas. After breathing the nitrous oxide, however, for some time, he threw the bag from him, kept breathing on laboriously with an open mouth, holding his nose with his left hand, without power to take it away, though aware of the ludicrousness of his situation. All his muscles seemed to be thrown into vibratory movement. He had a violent inclination to make antic gestures; seemed lighter than the atmosphere, and as if about to ascend. Before the experiment he was a good deal fatigued after a long ride; but the feeling left him during the respiration of the gas.

All these and analogous effects are daily produced by the exhibiters of this singular compound; and we have seen it annually given to a class for years without any of the indisposition resulting, which has been referred to by the French chymists. There are some, however, on whom its effects are less transitory and agreeable.

Two interesting cases of the kind are given by Professor Silliman, one of which we shall cite in his words, in consequence of the singular functional changes which the gas appears to have effected.

The subject of the case was a man of mature age, and of grave and respectable character. For nearly two years previous to his taking the gas, his health had been very delicate, and his mind frequently gloomy and depressed. This was particularly the case for a day preceding the inhalation, and his general health was such, that he was obliged to almost wholly discontinue his studies, and was about to invoke medical aid. In this state of bodily and mental debility, he inspired about three quarts of nitrous oxide. The consequences were, an astonishing invigoration of the whole system, and the most exquisite perceptions of delight. These were manifested by an uncommon disposition for pleasantry and mirth, and by extraordinary muscular power. The effects of the gas were felt undiminished for at least

thirty hours, and, in a greater or less degree, for more than a week. But the most remarkable effect was on the organs of taste. Before taking the gas, he had no peculiar choice of food, but after this, he manifested a taste for sweets only, and for several days ate nothing but sweet cake. This singular taste was, indeed, carried to such an excess, that he used sugar and molasses, not only upon his bread and butter, and lighter food, but upon his meat and vegetables. This he continued to do until the time when Professor Silliman wrote—eight weeks after the inhalation—when he was still found pouring molasses over beef, fish, poultry, potatoes, cabbage, or whatever animal or vegetable food was placed before him. His health and spirits were good, and he attributed the restoration of his strength and mental energy to the influence of the nitrous oxide. But these are rare cases.

The gas, according to the experiments of Dr. J. K. Mitchell, is possessed of considerable penetrative power. By this means, it can readily pass through the coats of the pulmonary vessels, get into the venous blood, and produce its effects directly upon the brain, in the same manner as other intoxicating substances.

Although capable of being respired, nitrous oxide is unfit to support life. Priestley found that this was the fact, and it has been confirmed by other chymists. Mice, introduced into a jar of it, die almost immediately, whilst in azote, hydrogen, and carbonic acid, they struggle for a short time.

Hydrogen.—This gas does not appear, from the experiments of Lavoisier, Sir H. Davy, and others, to exert any positively deleterious power when respired; and seems to destroy by excluding oxygen; hence, its effects are of a negative character. In a pure state, if the lungs have been previously emptied as far as possible, of atmospheric air, it can be breathed for a very short time only; quickly occasioning giddiness and a sense of suffocation; the countenance becoming livid, and the pulse sinking rapidly, followed by a state of insensibility.

When the gases were employed medicinally, hydrogen was used to diminish muscular power and sensibility, and a reduction of the force of the circulation, in catarrh, spitting of blood, consumption, &c.

Nitrogen or *azote*, when respired, exerts, like hydrogen, a negative influence, and proves fatal simply by excluding oxygen; an opinion, which, as Bostock properly remarks, might naturally be formed respecting a substance that enters so largely into the constitution of the atmosphere, and which, if it were possessed of any positively hostile properties, would be unfitted for its office, seeing that it is at all times received so largely into the lungs of animals.

Carburetted hydrogen gas.—This is the most active of the gases that are conceived to operate by depressing the vital functions. Even when largely diluted with atmospheric air, it occasions vertigo, sickness, diminution in the force and velocity of the pulse, re-

duction of muscular vigour, and every symptom of diminished power. In an undiluted state, it can scarcely be respired. Sir Humphry Davy found, that, at the third inspiration, total insensibility was induced, and symptoms of excessive debility continued for a considerable period; effects which sufficiently exhibit its positively deleterious agency. At one time, in a properly diluted condition, it was conceived to exert a beneficial effect in diseases of increased action; but it is now entirely laid aside.

Carbonic acid.—The experiments of Pilatre de Rozier and of Sir H. Davy have shown, that this gas proves more speedily fatal than either nitrogen or hydrogen; and there is every reason for believing that it excites spasmodic contraction of the glottis and suffocation. Sir H. Davy found, that air was still irrespirable when it contained three-fifths of its volume of carbonic acid, but that when the proportion was diminished to three parts in ten, it might be received into the lungs. The effects, which it occasioned, after being breathed for a minute, were slight giddiness and tendency to sleep. In pneumatic medicine, it was employed as a sedative in phthisis, being diluted with atmospheric air.

Carbonic oxide or *oxide of carbon* is a deleterious gas. Sir Humphry Davy took three inspirations of this gas, mixed with about one-fourth of common air; the effect was a temporary loss of sensation, succeeded by giddiness, nausea, acute pains in different parts of the body, and excessive debility. Some days elapsed before he entirely recovered. Mr. Witter, of Dublin, was struck with symptoms of apoplexy by breathing it, but was speedily restored by the inhalation of oxygen.

Sulphuretted hydrogen.—This gas is extremely deleterious. When respired in a pure state, it kills instantly, and its deadly agency is rapidly exerted when put in contact with any of the tissues, through which it penetrates with astonishing rapidity. Even when mixed with a portion of air, it has proved immediately destructive. Dr. Paris refers to the case of a chymist of his acquaintance, who was suddenly deprived of sense, as he stood over a pneumatic trough, in which he was collecting the gas.

From the experiments of Dupuytren and Thénard, air that contains a thousandth part of sulphuretted hydrogen kills birds immediately. A dog perished in air, containing $\frac{1}{100}$th part; and a horse in air, containing $\frac{1}{150}$th. It is the deleterious agent exhaled from privies, which has been so fatal, at times, to nightmen, who have been employed to remove or to cleanse them.

When this gas is breathed in a more dilute state, it produces powerful sedative effects, the pulse being rendered extremely small and weak, the contractility of the muscular organs considerably enfeebled, with stupor, and more or less suspension of the cerebral functions; and if the person recovers, he regains his strength very tardily.

Arsenuretted hydrogen also instantly destroys small animals, and

is extremely deleterious: it proved fatal to a German chymist, M. Gehlen.

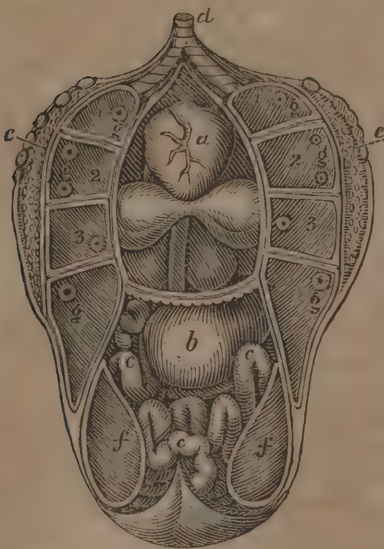
With regard to the other gases, the *ammoniacal gas*, *muriatic acid gas*, *nitrous acid gas*, *nitric oxide* or *deutoxide of azote*, and *chlorine*, they are completely irrespirable, producing spasmodic closure of the glottis, and asphyxia or suffocation.

According to the division already established, we may consider, then, that all these gases, when breathed in an undiluted condition, admit of being classed as follows:—

1. *Irrespirable gases.*	Carbonic acid, ammoniacal gas, muriatic acid gas, deutoxide of azote, nitrous acid gas, and chlorine.
2. *Negatively deleterious gases.*	Hydrogen, azote.
3. *Positively deleterious gases.*	Oxygen, protoxide of azote, carburetted hydrogen, carbonic oxide, sulphuretted hydrogen, and arsenuretted hydrogen.

In concluding the subject of respiration, we may briefly advert to the different modes in which the process is effected in the classes of animals, and especially in birds, the respiratory organs of which constitute one of the most singular structures of the animal economy. The lungs themselves,—as in the marginal figure of the lungs, &c. of the ostrich,—are comparatively small, and are adherent to the chest,—where they seem to be placed in the intervals of the ribs. They are covered by the pleura only on their under surface, so that they are, in fact, on the outside of the cavity of the chest. A great part of the thorax, as well as of the abdomen, is occupied by membranous air-cells, into which the lungs open by considerable apertures. Besides these cells, a considerable portion of the skeleton forms receptacles for air, in many birds; and if we break a long bone of a bird of flight, and blow into it, the body of the bird being immersed in water, bubbles of air will escape

Fig. 120.



Thoracic and abdominal viscera of the ostrich.

a. Heart, lodged in one great air-cell.—*b*. The stomach.—*c*. The intestines, surrounded by large air-cells.—*d*. The trachea dividing into bronchi.—*e*, *e*. The lungs.—1, 2, 3. *f*, *f*. Other great air cells, communicating with other cells and with the lungs.—*g*, *g*. The openings by which such communication is made.

from the bill. The object, of course, of all this, is to render the body light, and thus to facilitate its motions. Hence the largest and most numerous bony cells are found in such birds as have the highest and most rapid flight, as the eagle. The barrels of the quills are likewise hollow, and can be filled with air, or emptied at pleasure.

In addition to the uses just mentioned, these receptacles of air diminish the necessity of breathing so frequently, in the rapid and long-continued motions of several birds, and in the great vocal exertions of singing birds.

In fishes, in the place of lungs we find *branchiæ* or *gills*, which are placed behind the head on each side, and have a movable *gill-cover*. By means of the throat, which is connected with these organs, the water is conveyed to the gills, and distributed through them; by which means, the air, contained in the water, which according to Humboldt and Gay-Lussac, is richer in oxygen than that of the atmosphere, having 32 parts in the 100, instead of 20 or 21, comes in contact with the blood circulating through the gills. The water is afterwards discharged through the branchial openings,—*aperturæ branchiales*,—and consequently, they do not expire along the same channel as they inspire.

Lastly, in the insect tribe,—in the white-blooded animal,—we find the function of respiration effected altogether by the surface of the body; at least, so far as regards the reception of air, which passes into the body through apertures termed *stigmata*, the external terminations of *tracheæ* or air-tubes, whose office it is to convey the air to different parts of the system.

In all these cases we find precisely the same changes effected upon the inspired air, and especially, that oxygen has disappeared, and that carbonic acid is contained in nearly equal bulk in the residuary air.

CIRCULATION.

The next function to be considered is that by which the products of the various absorptions, converted into arterial blood in the lungs, are distributed to every part of the body,—a function of the most important character to the physiologist and the pathologist, and without a knowledge of which, it is impossible for the latter to comprehend the doctrine of disease.

Assuming the heart to be the great central organ of the function, every particle of the circulatory fluid must set out from it, be distributed through the lungs, undergo aeration there, be sent to the opposite side of the heart, whence it is distributed to every part of the system, and be thence returned, by the veins, to the right side, from which it set out,—thus performing a complete circuit.

It is not easy to ascertain the total quantity of blood, circulating in both arteries and veins. Many attempts have been instituted for this purpose, but the statements are most diversified, partly owing to the erroneous direction followed by the experimenters, but, still more, to the variation that must be perpetually occurring in the amount of fluid, according to age, sex, temperament, activity of secretion, &c. Harvey and the earlier experimenters formed their estimates, by opening the veins and arteries freely on a living animal, collecting the blood that flowed, and comparing this with the weight of the body. The plan is, however, objectionable, as the whole of the blood can never be obtained in this manner, and the proportion discharged varies in different animals and circumstances. By this method, Moulins found the proportion in a sheep to be $\frac{1}{23}$d; King, in a lamb, $\frac{1}{20}$th; in a duck, $\frac{1}{30}$th; and in a rabbit, $\frac{1}{30}$th. From these and other observations, Harvey concluded, that the weight of the blood of an animal is to that of the whole animal as 1 to 20. Drelincourt, however, found the proportion in a dog to be nearly $\frac{1}{10}$th; and Moor, $\frac{1}{12}$th.

An animal, according to Sir Astley Cooper, generally expires, as soon as blood, equal to about $\frac{1}{16}$th of the weight of the body, is abstracted. Thus, if it weighs sixteen ounces, the loss of an ounce of blood will be sufficient to destroy it: ten pounds will destroy a man weighing one hundred and sixty pounds; and, on examining the body, blood will still be found—in the small vessels especially—even although every facility has been afforded for draining them. Experiments have, however, shown, that no fixed proportion of the circulating fluid can be indicated as necessary for the maintenance of life. In the experiments of Rosa, asphyxia occurred in young calves when from three to six pounds, or from $\frac{1}{32}$d

to $\frac{1}{20}$th of their weight, had been abstracted, but in older ones not until they had lost from twelve to sixteen pounds, or from $\frac{1}{11}$th to $\frac{1}{9}$th of their weight. In a lamb, asphyxia supervened on a loss of twenty-eight ounces, or $\frac{1}{23}$th of its weight, and in a wether, of sixty-one ounces, or $\frac{1}{23}$d of its weight. Blundell found, that some dogs died after losing nine ounces or $\frac{1}{10}$th of their weight; and others withstood the abstraction of a pound, or $\frac{1}{10}$th of their weight; and Piorry affirms, that dogs can bear the loss of $\frac{1}{25}$th of their weight, but if a few ounces more be drawn they succumb.

From all the experiments and observations, Burdach concludes, that, on the average, death occurs when $\frac{3}{4}$ths or $\frac{7}{8}$ths, of the mass of blood is lost, although he has observed it in many cases, as in hæmoptysis, to supervene on the loss of $\frac{1}{4}$th, and even of $\frac{1}{8}$th.

The following table exhibits the computations of different physiologists, regarding the weight of the circulating fluid—arterial and venous.

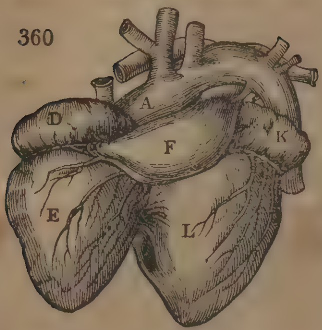
	lbs.		lbs.
Harvey, Lister, Mullen, Abildguard, Blumenbach,	8	F. Hoffmann,	28
		Haller,	28 to 30
		Young,	40
Lobb, Lower,	10	Hamberger,	80
Sprengel,	10 to 15		
Quesnai,	27	Keil,	100

Although the absolute estimate of Hoffmann is below the truth, his proportion is probably nearly accurate. He conceives, that the weight of the blood is to that of the whole body as 1 to 5. Accordingly, an individual, weighing one hundred and fifty pounds, will have about thirty pounds of blood; one of two hundred pounds, forty; and so on. Of this, one-third is supposed to be contained in the arteries, and two-thirds in the veins. The estimate of Haller is, perhaps, near the truth; the arterial blood being, he conceives, to the venous, as 4 to 9. If we assume, therefore, that the whole quantity of the blood is thirty pounds in a man weighing one hundred and fifty pounds,—which is perhaps allowing too much,—nine pounds, at least, may be contained in the arteries, and the remainder in the veins.

The lower classes of animals differ essentially, as we shall find hereafter, in their organs of circulation: whilst, in some, the apparatus appears to be confounded with the digestive; in others, the blood is propelled without any great central organ; and in others, again, the heart is but a single organ. In man, and in the upper classes of animals, the heart is *double*;—consisting of two sides, or really of two hearts, separated from each other by a septum.

Fig. 121.

360



Heart of the Dugong.

D. The right auricle.
E. The right ventricle.
K. The left auricle.
L. The left ventricle.
F. The pulmonary artery.
A. The aorta.

In the Dugong, the two ventricles are almost entirely detached from each other.

As all the blood of the body has to be emptied into this central organ, and to be subsequently sent from it; and as its flow is continuous, two cavities are necessarily required in each heart,—the one to receive the blood, the other to propel it,—which contract and dilate alternately. The cavity or chamber of each heart, which receives the blood, is called *auricle*, and the vessels that transport it thither are the *veins;* the cavity by which the blood is projected forwards is called *ventricle*, and the vessels, along which the blood is sent, are the *arteries*. One of these hearts is entirely appropriated to the circulation of venous blood, and has hence been called the *venous heart*, also the *right* or *anterior* heart, from its situation, and the *pulmonary* from the pulmonary artery arising from it. The other is for the circulation of arterial blood, and is hence called the *arterial heart*, also the *left* or *posterior*, from its situation, and the *aortic heart*, because the aorta arises from it.

Fig. 122.

The right and left hearts, separated.

a, a. Venæ cavæ ascendens, and descendens.—*b*. Right auricle.—*c, c*. Right ventricle.—*d*. Pulmonary artery.—*e*. Pulmonary veins.—*f*. Left auricle.—*g*. Left ventricle.—*h, h*. Aorta. The arrows indicate the course of the blood.

In figure 122, the two hearts are separated from each other, and shown to be distinct organs in the adult, although in the subject they seem to form but one organ. Between the two, after birth, there is not the slightest communication; and, consequently, every portion of blood, which has to attain the left side of the heart, must make the circuit through the lungs.

The whole of the ves-

sels, communicating with the right heart, contain venous blood; those of the left side, arterial blood.

If we consider the heart to be the centre, two circulations are accomplished, before the blood, setting out from one side of the heart, performs the whole circuit to the other. One of these consists in the transmission of the blood from the right side of the heart, through the lungs, to the left; the other in its transmission from the left side, along the arteries, and, by means of the veins, back to the right side. The former of these is called the *lesser* or *pulmonic*, the latter the *greater* or *systemic, circulation.*

The organs, by which these are accomplished, will require a more detailed examination.

Anatomy of the Circulatory Organs.

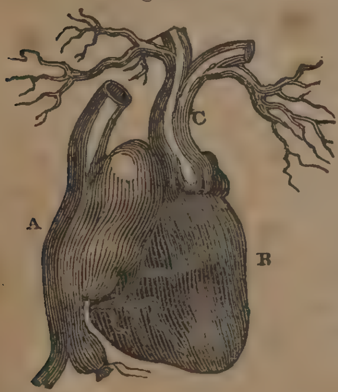
The circulatory apparatus is composed of the organs, by which the blood is put in motion, and along which it passes during its circuit.

To simplify the consideration of the subject, we shall consider the heart double; and that each system of circulation is composed of a *heart;* of *arteries*, through which the blood is sent from the heart; and of *veins*, by which the blood is returned to it. At the minute terminations of each of these, small vessels are situated, constituting, what has been called, the *capillary system.*

We shall first describe the central organ, as forming two distinct hearts; and afterwards as united.

The *pulmonic, right*, or *anterior heart*,—called also the *heart of black blood*,—is composed of an auricle and a ventricle. The *auricle*, so termed from some resemblance to an ear, is situated at the base of the organ, and receives the whole of the blood returning from various parts of the body by three veins;—the two venæ cavæ, and the coronary vein. The *vena cava descendens*, terminates in the auricle in the direction of the aperture by which the auricle communicates with the ventricle. The *vena cava ascendens*, the termination of which is directed more backwards, has the remains of a valve which is much larger in the fœtus, called the *valve of Eustachius.* The third vein is the *cardiac* or *coronary;* it returns the blood from the heart which has been carried thither by the coronary artery. In the septum, between the right and left auri-

Fig. 123.



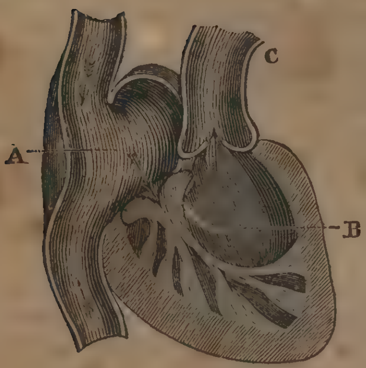
Pulmonic heart.

A. The right auricle with its venæ cavæ.—B. The right ventricle.—C. The pulmonary artery.

cle, there is a superficial depression, about the size of the point of the finger, which is the vestige of the foramen ovale,—an important part of the circulatory apparatus of the fœtus, as we shall see hereafter.

The opening, through which the auricle projects its blood into the ventricle, is situated downwards and forwards, as is seen in figure 124.

Fig. 124.



Section of the pulmonic heart.
A. Right auricle.—B. Right ventricle.—C. Pulmonary artery.

The inner surface of the *proper auricle*, or that which more particularly resembles the ear of a quadruped,—the remainder being sometimes called the *sinus venosus*, or *sinus venarum cavarum*,—is distinguished by having a number of *fleshy pillars* in it, which, from their supposed resemblance to the teeth of a comb, are called *musculi pectinati*. They are mere varieties, however, of the *columnæ carneæ* of the ventricles.

The right *ventricle* or *pulmonary ventricle* is situated in the anterior part of the heart; the base and apex corresponding to those of the heart. Its cavity is generally greater than that of the left side, and its parietes not so thick, owing to their merely having to force the blood through the lungs. It communicates with the auricle by the *auriculo-ventricular opening*—the *ostium venosum;* and the only other opening into it is that which communicates with the interior of the pulmonary artery. The opening, between the auricle and ventricle, is furnished with a tripartite valve, called *tricuspid* or *triglochin;* and the pulmonary artery has three others, called *sigmoid* or *semilunar*. From the whole edge of the tricuspid valve, next the apex of the heart, small, round, *tendinous cords*, called *chordæ tendineæ*, are sent off, which are fixed, as represented in figure 124, to the extremities of a few strong *columnæ carneæ*. These tendinous cords are of such a length as to allow the valve to be laid against the sides of the ventricle, in the distended state of that organ, and to admit of its being pushed back by the blood until a complete septum is formed during the contraction of the ventricle.

The *semilunar* or *sigmoid valves* are three in number, situated around the artery. When these fall together, there must necessarily be a space left between them. To obviate the inconvenience, that would necessarily result from the existence of such a free space, a small granular body is attached to the middle of the margin of

each valve; and, these coming together, as at A, Fig. 125, when the valves are shut down, complete the diaphragm, and prevent any blood from passing back to the heart. These small bodies are termed, from their reputed discoverer, *corpuscula Arantii*, and also *corpuscula Morgagnii;* or, from their resemblance to the seed of the sesamum, *corpuscula sesamoidea.* The valves, when shut, are concave towards the lungs, and convex towards the ventricle.

Fig. 125.

Immediately above them the artery bulges out, forming three sacculi or sinuses, called *sinuses of Valsalva.* These are often said to be partly formed by the pressure of the blood upon the sides of the vessels. The structure is doubtless ordained, and is admirably adapted for a specific purpose, viz. to allow the free edges of the valves to be readily caught by the refluent blood, and thus to facilitate their closure.

Within the right ventricle, and especially towards the apex of the heart, many strong eminences are seen, which are called *columnæ carneæ*, Fig. 124. These run in different directions, but the strongest of them longitudinally with respect to the ventricle. They are of various sizes, and form a beautifully reticulated texture. Their chief use probably is, to strengthen the ventricle and prevent it from being over-distended; in addition to which they may tend to mix the different products of absorption.

The *corporeal*, *left*, *aortic*, or *systemic* heart,—called also the *heart of red blood*,—has likewise an auricle and a ventricle.

The *left auricle* is considerably thicker and stronger but smaller than the right; and is likewise divided into *sinus venosus* and *proper auricle*, which form a common cavity. The columns, in the latter, are like those of the right auricle, but less distinct. From the under part of the auricle, a circular passage, termed *ostium arteriosum*, or auricular orifice, leads to the posterior part of the base of the cavity of the left ventricle. The left auricle receives the blood from the pulmonary veins.

The *left* or *aortic ventricle* is situated at the posterior and left part of the heart. Its sides are three times thicker and stronger than those of the right ventricle, to permit the much greater force which it has to exert; for, whilst the right ventricle merely sends its blood to the lungs, the left ventricle transmits it to every part of the body. It is narrower and rounder, but considerably longer, than the right ventricle, and forms the apex of the heart. The internal surface of this ventricle has the same general appearance as the other, but differs from it in having its columnæ carneæ larger, more numerous, firmer, and stronger.

In the aperture of communication with the corresponding auricle,

there is here, as in the opposite side of the heart, a ring or zone, from which a valve, essentially like the tricuspid, goes off. It is stronger, however, and divided into two principal portions only: the chordæ tendineæ are also stronger and more numerous. This valve has been termed *mitral*, from some supposed resemblance to a bishop's mitre.

At the fore and right side of the mitral valve, and behind the commencement of the pulmonary artery, a round opening exists, which is the mouth of the aorta. Here are three *semilunar valves*, with their *corpuscula Arantii*, exactly like those of the pulmonary artery, but a little stronger; and, on the outer side of the semilunar valves, are the *sinuses of Valsalva*, a little more prominent than those of the pulmonary artery.

The structure of the two hearts is the same. A serous membrane covers both, which is an extension of the inner membrane of the pericardium.

The substance of the heart is essentially muscular. The fibres run in different directions, longitudinally and transversely, but most of them obliquely. Many pass over the point, from one heart to the other, and all are so involved, as to render it difficult to unravel them. The cavities are lined by a thin membrane, forming, by its folds, the valves to which reference has been made. It differs somewhat in the two hearts;—being in one a prolongation of the inner coat of the aorta, and in the other of the venæ cavæ. On this account, the inner coat of the left heart is but slightly extensible, more easily ruptured, and considerably disposed to ossify; that of the right heart, on the other hand, is very extensible, not readily ruptured, and but little liable to ossify. The tissue of the heart is supplied with blood by the *cardiac* or *coronary arteries*—the first division of the aorta; and their blood is conveyed back to the right auricle by the *coronary veins*. The nerves, which follow the ramifications of the coronary arteries, proceed chiefly from a plexus, formed by the pneumogastric nerves, and great sympathetic.

In both hearts, the auricles are much thinner and more capacious than the ventricles; but they are themselves much alike in structure and size. The observation, that the right ventricle is larger than the left, is as old as Hippocrates, and has been attempted to be accounted for in various ways. Some have ascribed it to original conformation; others to the blood being cooled in its passage through the lung, and therefore occupying a smaller space when it reaches the left side of the heart. Haller and Meckel assert that it is dependent upon the kind of death; that if the right ventricle is usually more capacious, it is owing to the lung being one of the organs that yields first, thus occasioning accumulation of blood in the right cavities of the heart; and they state that they succeeded, in their experiments, in rendering either one or other of the ventricles more capacious, according as the cause of death arrested first the circulation in the lung or in the aorta; but the experiments of Legallois, and Seiler, especially of the former,—with mercury poured

into the cavities,—on dogs, cats, Guinea-pigs, rabbits, in the adult, the child, and the still-born fœtus, have shown, that, except in the fœtus, the right ventricle is more capacious, whether death has been produced by suffocation, in which the blood is accumulated in the right side of the heart, or by hæmorrhage; and Legallois thinks that the difference is owing to the left ventricle being more muscular, and, therefore, returning more upon itself.

The two hearts, united together by a median septum, form, then, one organ, which is situated in the middle of the chest, (see Fig. 115) between the lungs, and consequently in the most fixed part of the thorax.

According to Carus, the weight of the heart compared with that of the body is as 1 to 160. Weber found the proportion, in one case, as 1 to 150; and Laennec considered the organ to be of a healthy size, when equal to the fist of the individual.

Fig. 126 exhibits the heart in situ.

The heart is surrounded by its proper capsule, called the *pericardium*—a fibro-serous membrane, which is composed of two layers. The outermost of these is fibrous, semitransparent, and inelastic; strongly resembling the dura matter in its texture. Its thickness is greater at the sides than below, where it rests upon the diaphragm; or above, where it goes along the great vessels which communicate with the heart. The inner layer is of a serous character and lines the outer, giving the polish to its cardiac surface; it is then reflected over the heart, and adheres to it by cellular substance. Like other serous membranes, it secretes a fluid, which is termed the *liquor pericardii*, to lubricate the surface of the

Fig. 126.

1. Right auricle.
2. Right ventricle.
3. Left auricle.
4. Left ventricle.
5. Pulmonary artery.
6. Its left branch, which subdivides and passes to the left lung.
7. Commencement of the right branch which afterwards subdivides into:
7. 7. 7. Branches to the right lung.
8. 8. Aorta.
9. Vena cava descendens.
10. Vena cava ascendens.
11. Apex of the heart, formed by left ventricle.
12. 12. 12. 12. Pulmonary veins proceeding to left auricle.
13. 14. Coronary artery.

heart. This fluid is always found in greater or less quantity after death; and a question has arisen regarding the amount that must be considered morbid. This must obviously vary according to circumstances. It seldom, however, in the healthy condition, is above a tea-spoonful. When its quantity is augmented, along with inflammation of the membrane, the disease *hydropericarditis* exists.

The great use of the pericardium is probably to keep the heart constantly moist by the exhalation effected from it; and, also, to restrain the movements of the heart, which, under the influence of the emotions, sometimes leaps inordinately. If the pericardium be divided in a living animal, the heart is found to bound, as it were, from its ordinary position; and hence the expression—"leaping of the heart," during emotion—is physiologically accurate.

The *arteries* are solid, elastic tubes, which arise, by a single trunk, from the ventricle of each heart, and gradually divide and subdivide, until they are lost in the capillary system. The large artery, which arises from the left ventricle, and conducts the blood to every part of the body,—even to the lungs, so far as regards their nutrition,—is, as we have seen, the *aorta*, and that, which arises from the right ventricle and conveys the venous blood to the lungs, for aeration, is the *pulmonary artery*. Neither the one nor the other is a continuation of the proper tissue of the ventricles; the inner membrane is alone continuous, the muscular structure of the heart being united to the fibrous coat of the arteries, by means of an intermediate fibrous tissue.

The *aorta*, as soon as it quits the left ventricle, passes beneath the pulmonary artery, is entirely concealed by it, and ascends to form a curvature with the convexity upwards, the summit of which rises to within three-quarters of an inch or an inch of the superior edge of the sternum. This great curvature is called the *cross* or *arch of the aorta*. The vessel then passes downwards, from the top of the thorax to nearly as far as the sacrum, where it divides into two trunks, one of which proceeds to each lower extremity. In the whole of this course, it lies close to the spine, and gives off the various branches that convey arterial blood to the different parts of the body. Of the immense multitude of these ramifications, an idea may be formed, when we reflect, that the finest pointed needle cannot be run into any part of the surface of the body, without blood,—probably both arterial and venous,—flowing.

The larger arteries are all situated deeply, and are thus remote from external injury. They communicate freely with each other, and their anastomoses are more frequent as the arteries become smaller and farther from the heart. At their final terminations, they communicate with the veins and the lymphatics.

The branches of the aorta, when taken collectively, are of greater capacity than the parent trunk, and this inequality goes on augmenting; so that the ultimate divisions of an artery are of a much greater capacity than the trunk of the vessel. Hence, the arterial

system has been considered to represent, in the aggregate, a cone, whose apex is at the heart, and the base in the organs.

As all the minute arterial ramifications are not visible, it is obviously impracticable to discover the ratio between their united capacity and that of the aorta at its origin; yet the problem has been attempted. Keil, by experiments made upon an injected subject, considered it to be as 44507 to 1. J. C. A. Helvetius, and Sylva as 500 to 1. Senac estimated, not their capacities but their diameters, and he conceived the ratio of these to be as 118,490 to 90,000; and George Martine affirmed, that the calibre of a parent arterial trunk is equal to the cube root of the united diameters of the branches.

The *pulmonary artery* strongly resembles the aorta. Its distribution has been already described as a part of the respiratory organs.

The *arteries* are composed of different coats in superposition, respecting the number of which anatomists have not been entirely of accord. Some have admitted five, others four, but, at the present day, three only are received;—first, an *external* or *cellular*, called also *nervous*, and *cartilaginous* by Vesalius, and *tendinous* by Heister, which is formed of condensed cellular substance, and has considerable strength and elasticity, so that if a ligature be applied tightly round the vessel, the middle and internal coats will be completely cut through, whilst the outer coat may remain entire. Scarpa is not disposed to admit this as one of the coats. He considers that it is only an exterior envelope, to retain the vessel *in situ*.

The next coat is the *middle*, *muscular*, or *proper* coat, the character of which has been the subject of much discussion. It is composed of yellow, circular fibres, which do not appear individually to pass entirely round the vessel. This coat was, at one time, almost universally believed to be muscular. Such was the opinion of Hunter; and hence the muscularity of the arteries was invoked as an agent in the circulation. Careful examination does not, however, exhibit the characters of the muscular tissue. The latter is soft, extensible, contractile, and of a red colour; the arterial tunic is firm, solid, elastic, easily ruptured, and of a yellow colour. Nysten and Magendie applied the galvanic stimulus to it, but without effect; and it is known, that this is the most sensible test of irritability. The middle coat appears to be a tissue of a peculiar character, the base of which is formed by the *tissu jaune* or yellow tissue of the later comparative anatomists.

The *third* or *inner coat* is smooth and polished, and is a continuation of the membrane which lines the ventricles. It is generally described as lubricated by a kind of serous exhalation.

The arteries receive the constituents that belong to every living part,—arteries, veins, lymphatics, and nerves. The arteries proceed not from the vessels themselves, which they nourish, but from adjacent trunks, as we have remarked of the *vasa vasorum*, to which class they really belong. The nerves proceed from the great sympathetic, form plexuses around the vessels, and accompany them

through all their ramifications. By some anatomists, the arteries of the head, neck, thorax and abdomen, are conceived to be supplied from the great sympathetic, whilst those of the extremities are derived from the nerves of the spinal marrow. It is probable, however, that more accurate discrimination might trace the dispersion of the twigs of the great nervous system of involuntary motion on all these vessels.

The organization of the arteries renders them very tough and extremely elastic, both of which qualities are necessary to enable them to withstand the impulse of the blood sent from the heart, and to react upon the fluid so as to influence its course. It is, likewise, by virtue of this structure, that the parietes retain their form in the dead body, one of the points that distinguish them from the veins.

The vitality of the arteries is inconsiderable. Hence their diseases are by no means numerous or frequent; an important fact, seeing that their functions are eminent, and their activity incessant.

The *capillary vessels* are the vessels of extreme minuteness, by some considered to be formed by the termination of the arteries and the commencement of the veins, by others, to be a distinct set of vessels. This system of vessels, forms a plexus, which is distributed over every part of the body, and constitutes, in the aggregate, the *capillary system.* It admits of two great divisions, one of which is situated at the termination of the branches given off from the aorta, and is called the *general capillary system;* the other forming the branches of the pulmonary artery,—the *pulmonic capillary system.*

Although the capillary system of man does not admit of detection by the unaided sight, its existence is evidenced by the microscope; by injections, which can develope it artificially in almost every organ; by the application of excitants, and by inflammation. The parietes of the vessels often cannot be distinguished from the substance of the organs;—the colour of the blood, or the matter of the injection alone indicating their course. In some parts, these vessels are so minute as not to admit the red particles of the blood, whilst, in others, the red particles always circulate. This diversity has given rise to the distinction of the capillaries into *red* and *white.* There are certain textures, which receive neither the one class nor the other, as the corneous and epidermeous.

The ancients were of opinion, that the arteries and veins are separated by an intermediate substance, consisting of some fluid effused from the blood, and which they called, in consequence, *parenchyma.* The notion is, indeed, still entertained, and is supported by microscopical observations, neither very definite, nor very intelligible. It is said, that the microscope, in the examination of delicate and transparent tissues, exhibits currents of moving globules, with many spaces of apparently solid substance, resembling small islets, surrounded by an agitated fluid. But if it be irritated, by thrusting a fine needle into it, the motion of the globules becomes more rapid, new currents arise where none were pre-

viously perceptible, and the whole becomes a mass of moving particles, the general direction of which tends towards the point of irritation. There are reasons, however, for the belief, that the communication between the arteries and the veins is more direct. The substance of an injection passes from one set of vessels into the other without any evidence of intermediate extravasation. The blood has been seen, too, passing, in living animals, directly from the arteries into the veins. Leeuenhoek and Malpighi, on examining the swim-bladders, gills, and tails of fishes, the mesentery of frogs, &c.—which are transparent,—saw this distinctly; and the fact has been proved by the observations of Cowper, Cheselden, Hales, Spallanzani, Thomson, Erman, Cuvier, Configliachi, Rusconi, Döllinger, Carus, and others. The artery and vein terminate in two different ways, at times, after the artery has become extremely minute, by sending off numerous lateral branches, as Haller states he noticed in the swim-bladders of fishes; at others, by proceeding parallel to each other, and communicating by a multitude of transverse branches. This communication takes place between both the red and the white capillaries and their corresponding veins.

The capillary vessels have been esteemed, by some, to belong chiefly to the arteries, the venous radicles not arising almost imperceptibly from the capillary system, as the arteries terminate in it, but having a marked size, at the part where they quit this system, which strikingly contrasts with the excessive tenuity of the capillary arterial vessels, whilst, between the capillary system and the arteries there is no distinct line of demarcation. The opinion of Bichat was, that this system is entirely independent of both arteries and veins; and Autenrieth imagined, that the minute arteries unite to form trunks, which again divide before communicating with the veins, so as to represent a system analogous to that of the vena portæ. The experiments of Dr. Marshall Hall, on the batrachia, which were performed with signal care, led him to the following conclusions, which agree with those of Bichat, so far as regards the independent existence of a capillary system. The minute vessels, he says, may be considered as arterial, so long as they continue to divide and subdivide into smaller and smaller branches. The minute veins are the vessels that gradually enlarge from the successive addition of smaller roots. The true capillary vessels are distinct from these. They do not become smaller by subdivision, nor larger by conjunction, but they are characterized by continual and successive union and division, or anastomoses, whilst they retain a nearly uniform diameter. The last branches of the arterial system, and the first root of the venous, Dr. Hall remarks, may be denominated minute, but the term "capillary" must be reserved for, and appropriated to, vessels of a distinct character and order, and of an intermediate station, carrying red globules, and perfectly visible by means of the microscope.

The capillary arteries are distinct in structure—as we shall see

they are in office—from the larger arteries. All the coats of these minute vessels diminish in thickness and strength, as the tubes lessen in size, but more especially the middle coat, which, according to Wedemeyer, may still be distinguished by its colour in the transverse section of any vessels whose calibre is not less than the tenth of a line; it entirely disappears in vessel too small to receive the wave of blood in a manifest jet. But, while the coats diminish, the nervous filaments, distributed to them, increase; the smaller and thinner the capillary, the greater the proportionate quantity of its nervous matter. The coats of the capillaries, becoming successively thinner and thinner, at length disappear altogether, and the vessels alternately terminate in membraneless canals formed in the substance of the tissues. The blood is contained, according to Wedemeyer, Gruithuisen, Döllinger, and Carus, in the different tissues, in channels, which it forms in them; even under the microscope, the stream is seen to work out for itself, easily and rapidly, a new passage in the tissues, which it penetrates, and it seems certain, that in the figura venosa of the egg, the blood is not surrounded by vascular parietes.

Of these fine capillaries, some, according to Wedemeyer, communicate with veins. In the others, there are no visible openings or pores in the sides or ends, by which the blood can be extravasated, preparatory to its being imbibed by the veins. There is nowhere apparent a sudden passage of the arterial into the venous stream; no abrupt boundary between the division of the two systems. The arterial streamlet winds through long routes before it assumes the nature, and takes the direction of a venous streamlet. The ultimate capillary rarely passes from a large arterial into a large venous branch.

Many speculations have, however, been indulged, regarding the mode in which the vascular extremities of the capillary system are arranged. Bichat regarded it as a vast reservoir, whence originate, besides veins, vessels of a particular order, whose office it is to pour out, by their free extremity, the materials of nutrition,—vessels, which had been previously imagined by Boerhaave, and are commonly known under the appellation of *exhalants.* Mascagni supposed that the final arterial terminations are pierced, towards their point of junction with the veins, by lateral pores, through which the secreted matters transude. These points, will farther engage attention under the head of *secretion.*

The *veins* have already been described under *venous absorption.*

Physiology of the Circulation.

The blood, contained in the circulatory apparatus, is in constant motion, and this in one direction. The venous blood, brought from every part of the body, is emptied into the right auricle; the right auricle sends it into the corresponding ventricle; the latter

projects it into the pulmonary artery, by which it is conveyed to the lungs, passing through the capillary system into the pulmonary veins. These convey it to the left auricle; the left auricle sends it into the corresponding ventricle; and the left ventricle into the aorta, along which it passes to the different organs and tissues of the body, through the general capillary system, which communicates with the veins; these last vessels return the blood to the part whence it set out. This entire circuit includes both the lesser and the greater circulation.

It was not until the comencement of the seventeenth century, that any precise ideas were entertained regarding the general circulation. In antiquity, the most erroneous notions prevailed; the arteries being generally looked upon as tubes for the conveyance of some aerial fluid to, and from, the heart, whilst the veins conducted the blood, but whither or for what precise purpose was not understood. The names, given to the principal arterial vessel—the *aorta* —and to the *arteries*, sufficiently show the functions originally ascribed to them, both being derived from the Greek, αηρ, air, and τηρειν, to keep; and this is farther confirmed by the fact, that the trachea or windpipe was originally termed an artery,—the αρτηρια τραχεια of the Greeks,—the *aspera arteria* of the Latin writers.

In the time of Galen, however, the arteries were known to contain blood; and he seems to have had some faint notions of a circulation. He remarks, that the chyle, the product of digestion, is collected by the meseraic veins and carried to the liver, where it is converted into blood; the supra-hepatic veins then convey it to the pulmonary heart; thence it proceeds in part to the lungs, and the remainder to the rest of the body, passing through the median septum of the auricles and ventricles.

This limited knowledge of the circulation continued through the whole of the middle ages; the functions of the veins being universally misapprehended; and the general notion being, that they also convey blood from the heart to the organs; from the centre to the circumference. It was not until after the middle of the sixteenth century, that the lesser circulation, or that through the lungs, was comprehended, by the labours of Michael Servetus,—who fell a victim to the persecutions and intolerance of Calvin,—of Andrew Caesalpinus, and of Realdus Columbus. It has, indeed, been imagined, that they possessed some notion of the greater circulation. However this may have been, all nations unite in awarding to Harvey the merit, if not of entire originality, of at least having first clearly described it. The honour of the discovery is, therefore, his; and by it his name has been rendered immortal, for its importance in the physiology and pathology of the animal fabric is overwhelming. How vague and inaccurate, indeed, must have been the notions of the earlier pathologists regarding the doctrine of acute diseases, in which the circulation is always largely affected—diseases, which,

according to the estimate of some writers, constitute two-thirds of the morbid states to which mankind are liable. It was in the year 1619, that Harvey attained a full knowledge of the circulation; but his discovery was not promulgated until the year 1628; in a tract, under the title—"*exercitatio anatomica de motu cordis et sanguinis,*" to which the merit of clearness, perspicuity and demonstration has been awarded by all. Yet so strong is the force of prejudice, and so difficult is it to discard preconceived notions, that it was remarked, according to Hume, that no physician in Europe, who had reached forty years of age, ever, to the end of his existence, adopted Harvey's doctrine of the circulation; and Harvey's practice in London diminished extremely for a time from the reproach drawn upon him by that great and signal discovery.

Of the truth of the course of the blood, as established by Harvey, we have numerous, incontestable evidences, which it may now be almost a work of supererogation to adduce. We will briefly refer to some of the most striking. *First.* If we open the chest of a living animal, we find the heart alternately dilating and contracting so as manifestly to receive and expel the blood in reciprocal succession. *Secondly.* The valves of the heart, and of the great arteries, which arise from the ventricles, are so arranged as to allow the blood to flow in one direction, and not in another; and the same may be said of those of the veins, which are directed towards the heart. The tricuspid valve permits the blood to flow only from the right auricle into the corresponding ventricle; the sigmoid valves admit it to enter the pulmonary artery, but not to return; and, as there is no immediate communication between the right and left sides of the heart, the blood must pass along the pulmonary artery and by the pulmonary veins to the left auricle. The mitral valve, again, is so situated, that the blood can only pass in one direction from auricle to ventricle; and, at the mouth of the aorta, the same valvular arrangement exists, as at the mouth of the pulmonary artery, permitting the blood to proceed along the artery, but preventing its reflux. *Thirdly.* If an artery and a vein be wounded, the blood will be observed to flow from the part of the vessel nearest the heart in the case of the artery; from the other extremity in that of a vein. The ordinary operation of blood-letting at the flexure of the arm affords us an elucidation of this. The bandage is applied above the elbow, for the purpose of compressing the superficial veins, but not so tightly as to compress, also, the deep-seated artery. The blood passes along the artery to the extremity of the fingers, and returns by the veins, but its progress back to the heart by the subcutaneous veins being prevented by the ligature, they become turgid; and, if a puncture be made, the blood flows freely. If, however, the ligature be applied so forcibly as to compress the main artery; the blood no longer flows to the extremity of the fingers; there is none, consequently, to be returned by the veins. They do not rise properly; and if a puncture be made no blood flows. This is not an infrequent cause

of the failure of an inexperienced phlebotomist. If the bandage, under such circumstances, be slackened, the blood will resume its course along the artery, and a copious stream will issue from the orifice, which did not previously transmit a drop. This operation, then, exhibits the fact of the flow of blood along the arteries from the heart, and of its return by the veins. From what has been said, too, it will be obvious, that if a ligature be applied to both vessels, the artery will become turgid above the ligature, the vein below it. *Fourthly.* The microscopical experiments of Leeuenhoek, Malpighi, Spallanzani, and others, have exhibited to the eye the passage of the blood in successive waves by the arteries towards the veins, and its return by the latter. *Lastly.* The fact is farther demonstrated by the effects of transfusion of blood, and of the injection of substances into the vessels; both of which operations will be alluded to in another place.

In tracing the physiological action of the different parts of the circulatory apparatus, we shall follow the order observed in the anatomical sketch; and describe, in succession, the circulation in the heart, in the arteries, in the capillary vessels, and in the veins; on all of which points there has been much interesting diversity of opinion; and much room for ingenious speculation; and, for farther improvement.

1. *Circulation in the heart.*—It has been already observed, that when the heart of a living animal is exposed, it is remarked to undergo alternate contraction and dilatation; the auricles, on each side, contracting, and the ventricles at the same time dilating. The latter then enter into contraction, and the auricles dilate simultaneously;—so that the blood is received into the two auricles, at the same time, and is transmitted into the two great arteries synchronously.

In order that the heart shall receive blood, it is necessary that the auricle should be dilated. This movement is probably effected by virtue of the elasticity, which it possesses in its structure. Let us suppose it to be once filled; the stimulus of the blood excites it to contraction, and the blood is thus sent into the corresponding ventricle. As soon, however, as it has emptied itself, the stimulus is withdrawn; and, by virtue of its elasticity, it returns to the state in which it was prior to contraction. An approach to a vacuum is thus formed in the cavity, and the blood is solicited towards it from the veins, until it is again filled and its contraction is renewed. When the right auricle contracts there are four channels by which the blood might be presumed to pass from it,—the two terminations of the venæ cavæ, the coronary vein, and the auriculo-ventricular communication. The constant flow of blood from every part of the body prevents it from returning by the venæ cavæ, whilst the small quantity, which, under other circumstances, might have entered the coronary vein, is prevented by its valve. To the flow of the blood through the aperture into the ventricle, which is in a state of

dilatation, there is no obstacle, and accordingly it takes this course, raising the tricuspid valves.

It may be remarked, that physiologists are not entirely of accord regarding the reflux of blood into the venæ cavæ. Some think, that this always occurs to a slight extent: others, that it is never present in the physiological or healthy state. Its existence is unequivocal, where an obstacle occurs to the due discharge of the blood into the ventricle. For example, if any impediment exists to the flow of blood along the pulmonary artery, either owing to mechanical obstruction or to diminished force of the ventricle, the reflux will be manifested by a kind of pulsation in the veins, which Haller has called the *venous pulse*.

The blood, having attained the right ventricle, by the effort exerted by the contraction of the auricle, and by the aspiration excited by the dilatation of the cavity through the agency of its elastic structure, the ventricle contracts. Into it there are but two apertures,—the auriculo-ventricular, and the mouth of the pulmonary artery. By the former, the blood cannot escape, owing to the tricuspid valve which acts like the sail of a ship,—the blood distending it, as the wind does a sail, and the chordæ tendineæ retaining it in position, so that the blood is precluded from reflowing into the auricle. The only way it can escape is by the pulmonary artery, the sigmoid valves of which it raises. These had been closed, like flood-gates, during the dilatation of the ventricle; but they are readily pushed outwards, by the column transmitted from the ventricle.

Such is the circulation through one heart,—the *pulmonic*. The same explanation applies to the other,—the *systemic;* and hence it is, that the structure, as well as the functions of the heart, is so much better comprehended, by conceiving it to be constituted of two essentially similar organs.

We have said, that the right and left auricles contract and dilate together, and that the same remark applies to the contraction and dilatation of the two ventricles. To that condition of the heart, in which the ventricles are dilated, and the auricles synchronously contracted, the term *diastole* has been applied; and, to that in which the ventricles are contracted and the auricles synchronously dilated,—*systole*. Nichols, the son-in-law and successor of Mead, distinguished six intervals,—the contraction of the right auricle; of the right ventricle; of the pulmonary artery; of the left auricle; of the left ventricle; and of the aorta, but as the auricles dilate and contract together, and the same applies to the ventricles, the division into *systole* and *diastole* is sufficient; as, however, the most striking phenomenon in the action of the heart is the contraction of the ventricles, systole is usually applied to their contraction, and diastole to their dilatation; consequently, during the period of systole, the auricles are dilated, and during that of diastole, contracted. Such is the opinion generally entertained of the *rôle* performed by each portion of the heart in the circulation; but it is proper to remark,

that, in some animals, the auricles are altogether wanting; that M. Despine considers the auricles, in receiving or transmitting the blood, to have only a vermicular motion, instead of one of contraction; and that Dr. T. Robinson of Petersburgh, in the case of a malformed fœtus described in the twenty-second number of the "American Journal of the Medical Sciences," could not detect a distinct systole and diastole of the auricles.

Since the valuable improvement, introduced by Laennec, in the discrimination of diseases of the chest by audible evidences, it has been discovered, that the heart is not in a state of incessant activity, but that it has, like other muscles, its intervals of repose. If we apply the ear or the stethoscope to the præcordial region, we hear, first, a dull, lengthened sound, which, according to Laennec, is synchronous with the arterial pulse, and is produced by the contraction of the ventricles. This is instantly succeeded by a sharp, quick sound, like that of the valve of a bellows or the lapping of a dog. This corresponds to the interval between two pulsations, and is owing to the contraction of the auricles. The space of time, that elapses between this and the sound of the contraction of the ventricles, is the period of repose. The relative duration of these periods is as follows:—one-half, or somewhat less, for the contraction of the ventricles; a quarter, or somewhat more, for the contraction of the auricles; and the remaining quarter for the period of total cessation from labour. So that in the twenty-four hours the ventricles work twelve hours and rest twelve; and the auricles work six and rest eighteen.

Such is the view of Laennec; but it is manifestly erroneous. Ocular observations on living animals, as Dr. Alison has remarked, show that the contraction of the auricle precedes that of the ventricle, and that the interval of rest is between the contraction of the ventricle, and the next contraction of the auricle; between the contraction of the auricle and that of the ventricle there is no appreciable interval. M. Despine thinks that the first sound is produced by the contraction of the ventricle, and that the second is owing to their dilatation.

Our knowledge, indeed, of the cause of the sounds rendered by the heart, is sufficiently imprecise: this is farther proved by the circumstance, that, whilst Magendie ascribes the first sound to the shock or impulsion of the apex of the heart during its diastole, and the second to the impulsion of the base of the heart during its systole, Bouillaud, after direct examination, attributes the double sound or tic-tac to the play of the valves of the heart. Rouanet, again, ascribes the first or dull sound to the shock or impulse of the tricuspid and mitral valves against the auriculo-ventricular orifices, and the second or clear sound to the succussion of the blood in the distended aorta and pulmonary artery backwards against the semilunar valves, during the dilatation of the ventricles. Mr. Carlile refers the first sound, with Laennec, to the systole of the ventricles, and the second to the

obstacle presented by the semilunar valves to the return of the blood from the arteries into the heart;—and Messrs. Corrigan, Pigéaux and Stockes think the first sound to be owing to the systole of the venous sinuses, and the second to the systole of the ventricles —an opinion, which Burdach thinks is best founded. Farther observations are, however, necessary, but it seems to us, that, in the present state of our knowledge, the view of Mr. Carlile is most in accordance with observed phenomena.

It has been a question with physiologists, whether the cavities of the heart completely empty themselves at each contraction. Senac, and Thomas Bartholine, from their experiments, were long ago led to answer the question negatively. On the other hand, Haller entertained an opposite opinion,—suggested, he remarks, by his experiments, but, perhaps, notwithstanding all his candour, connected, in some manner, with his doctrine of irritability, which could not easily admit the presence of an irritant in a cavity which had ceased to contract. It has been remarked by Magendie, that if we notice the heart of a living animal, whilst it is in a state of action, it is obvious, that the extent of the contractions cannot have the effect of completely emptying the auricle or the ventricle; but it must, at the same time, be admitted, that such experiments are inconclusive, inasmuch as they exhibit to us the action of the organ under powerfully deranging influences, and such as could be readily conceived to modify materially the extent of the contractions. They certainly are insufficient to prove, that, whilst an animal is in a physiological condition, the auricles and ventricles are not emptied of their contents by their contraction.

The objection, that has been urged against the opposite view, that there would always be stagnant blood in the cavities of the heart, is not valid. The experiments of Venturi, on the lateral communication of motion in fluids, have shown, that even in an ordinary hydraulic apparatus, the motion of a stream, passing through a vessel of water, is communicated to the fluid, which is at rest in the vessel, so that an incessant change is produced.—Let us suppose a stream of water to enter the vessel D E F B,

Fig. 127.

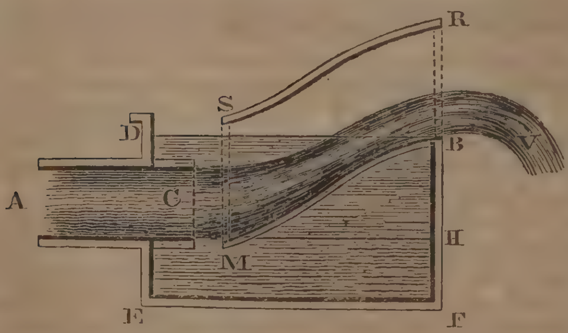


Fig. 127, which is full of fluid, by the pipe A C, and that opposite

to this pipe is the tube S M B R. The stream will pass up this tube higher than the vessel, and discharge itself at B V. At the same time, the fluid in the vessel will be observed to be in motion, and, in a few seconds, the level in the vessel will fall from D B to M H.

During the systole of the heart, the organ is suddenly carried forwards; and although it appears to be rendered shorter, its point strikes the left side of the chest opposite the interval between the sixth and seventh true ribs; producing what is called the "beating of the heart." The cause of this phenomenon was, at one period, a topic of warm controversy. Borelli, Winslow and others affirmed, that it was owing to the organ being elongated during contraction; but to this it was replied by Bassuel, that if such elongation took place, the tricuspid and mitral valves, kept down by the columnæ carneæ, could not possibly close the openings between the corresponding auricles and ventricles. Senac ascribed the beating of the heart to three causes, and his views have been adopted by most physiologists:—1, to the dilatation of the auricles, which occurs during the contraction of the ventricles; 2, to the dilatation of the aorta and pulmonary artery by the introduction of the blood, sent into them by the ventricles; and 3, to the straightening of the arch of the aorta, owing to the blood being forced against it by the contraction of the left ventricle. Dr. Wm. Hunter considered the last cause quite sufficient to explain the phenomenon, and many physiologists have assented to his view. More recently, Dr. Barry has instituted some experiments upon this subject. He opened the thorax of a living animal, and, by passing his hand into the cavity, endeavoured to ascertain the actual condition of the heart and great vessels, as to distention and relative position. He performed seven experiments of this kind, from which he concluded, that the vena cava is considerably increased in size during inspiration, which he ascribes, as will be better understood hereafter, to the partial vacuum then formed in the chest. He supposes, that the force exerted by the venous blood on entering the heart, in consequence of the expansion of the chest and the great vessels behind the heart, pushes the organ forwards, and thus causes it to strike against the ribs.

The great agent is probably the expansive force of the heart, which tends to project it forwards. It is obvious, that as the heart is altogether fixed by its base, and as every force, exerted upon it, must take effect upon that part, the organ may, in this manner, readily move upon its base, and accomplish the percussion in question.

The systole of the heart is admitted by all to be active; but some physiologists are disposed to think the diastole passive—that is—the effect of relaxation of the fibres or of the cessation of contraction. Pechlin, Perrault, Hamberger, Despine, Alison, and numerous others, have supported an opposite view;—affirming that direct experiment on living animals shows, that positive effort is exerted at the time of the dilatation of the cavities;—a view strikingly confirmed by

the case of monstrosity, related by Dr. Robinson. His opinion is, that the force of the diastole was in that case, equal to, if not greater than that of the systole. Dr. Roget, in alluding to the views on this subject, suggests, that if the course of all the fibres, composing the muscular parietes of the organ, were better known, this apparent anomaly might perhaps be as easily explained as in the ordinary case of antagonist muscles. It is probable, however, that the active force, exerted in the dilatation of these cavities, is that of elasticity; and that when the contraction of the muscular fibres has ceased, this is aroused to action, and promptly restores the organ to its previously dilated condition. According to this view, the natural state would be that of dilatation. We shall see, hereafter, that this elasticity is probably one of the agents of the circulation of the blood along the vessels.

The cause of the heart's action has been a deeply interesting question to the physiologist, and, in the obscurity of the subject has given rise to many and warm controversies. From the first moment of fœtal existence, at which the heart becomes perceptible, till the cessation of vitality, it continues to move. By many of the ancients this was supposed to be owing to an inherent *pulsific virtue*, which enabled it to contract and dilate alternately,—a mode of expression, which, in the infancy of physical science, was frequently employed to cover ignorance, and which has been properly and severely castigated by Molière:—

> "Mihi a doctore
> Demandatur causam et rationem quare
> Opium facit dormire.
> A quoi respondeo.
> *Quia est in eo*
> *Virtus dormitiva,*
> Cujus est natura
> Sensus assoupire."

Descartes imagined, than an explosion took place in the ventricles as sudden as that of gunpowder. With equal nescience the phenomenon was ascribed, by Van Helmont, to his imaginary archæus; and by Stahl, and the rest of the animists, to the *anima*, soul, or intelligent principle, which is supposed to preside over all the mental and corporeal phenomena.

Stahl was, however, one of the first that attempted any rational explanation of the heart's action. Its muscular tissue; the similarity of its contractions to those of ordinary muscles, with the exception of their not being voluntary; the fact of its action being modified by the passions, &c. led him to liken its movements to those of ordinary muscles. He admitted, that, generally, we possess neither perception of, nor power over, its motions; but he affirmed, that habit alone had rendered them involuntary; in the same manner as certain muscular twitchings or *tics*, which are at first voluntary, may become irresistible by habit. A strong confirmation of this opinion

was drawn from the celebrated case of the honourable colonel Townshend, called by Adelon and other French writers, Towson, who was able, (not all his life, as Adelon asserts, but, a short time before his death,) to suspend the movements of his heart at pleasure. This case is of such a singular character, in a physiological as well as pathological point of view, that we shall give it in the words of Dr. George Cheyne, one of the physicians who attended him, and whose character for veracity is beyond suspicion.

"Colonel Townshend, a gentleman of excellent natural parts, and of great honour and integrity, had, for many years, been afflicted with constant vomitings, which had made his life painful and miserable. During the whole time of his illness he had observed the strictest regimen, living on the softest vegetables and lightest animal food; drinking asses' milk daily, even in the camp; and for common drink, Bristol water, which, the summer before his death, he had drank on the spot. But his illness increasing, and his strength decaying, he came from Bristol to Bath in a litter, in autumn, and lay at the Bell Inn. Dr. Baynard, who is since dead, and I were called to him, and attended twice a day for about the space of a week: but, his vomitings continuing still incessant, and obstinate against all remedies, we despaired of his recovery. While he was in this condition, he sent for us early one morning; we waited on him with Mr. Skrine, his apothecary, (since dead also;) we found his senses clear, and his mind calm; his nurse and several servants were about him. He had made his will and settled his affairs. He told us he had sent for us to give him some account of an odd sensation he had for some time observed and felt in himself, which was that composing himself, he could *die* or *expire* when he pleased, and yet by an effort or somehow, he could come to life again; which it seems he had sometimes tried before he had sent for us. We heard this with surprise; but as it was not to be accounted for from tried common principles, we could hardly believe the fact as he related it, much less give any account of it; unless he should please to make the experiment before us, which we were unwilling he should do, lest in his weak condition he might carry it too far. He continued to talk very distinctly and sensibly above a quarter of an hour about this (to him) surprising sensation, and insisted so much on our seeing the trial made, that we were at last forced to comply. We all three felt his pulse first; it was distinct, though small and thready; and his heart had its usual beating. He composed himself on his back, and lay in a still posture some time. While I held his right hand, Dr. B. laid his hand on his heart, and Mr. S. held a clean looking-glass to his mouth. I found his pulse sink gradually, till at last I could not feel any, by the most exact and nice touch. Dr. Baynard could not feel the least motion in his heart, nor Mr. Skrine the least soil of breath on the bright mirror he held to his mouth. Then each of us, by turn, examined his arm, heart and breath, but could not by the nicest scrutiny discover the least symptom of

life in him. We reasoned a long time about this odd appearance as well as we could; and all of us judging it inexplicable and unaccountable; and finding he still continued in that condition, we began to conclude indeed that he had carried the experiment too far, and at last were satisfied that he was actually dead, and were just ready to leave him. This continued about half an hour, by nine o'clock in the morning, in autumn. As we were going away, we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning; he began to breathe gently, and speak softly; we were all astonished, to the last degree, at this unexpected change, and after some farther conversation with him, and among ourselves, went away fully satisfied as to all the particulars of this fact, but confounded and puzzled, and not able to form any rational scheme, that might account for it. He afterwards called for his attorney, added a codicil to his will, settled legacies on his servants, received the sacrament, and calmly and composedly expired about five or six o'clock that evening."

It is manifest that this case—unaccountable as it is, in many respects—can add no weight to the views of the Stahlians. It is as unique as it is inexplicable. The opinion, that the heart's action is a muscular function, was accurate. The error lay in placing it amongst the voluntary functions. It belongs to the involuntary class, equally with many of the muscles concerned in deglutition, and with those of the stomach and intestines.

The doctrine of Haller, on this subject, rested upon the *vis insita* or *irritability*, to which he referred all muscular contractions, whether voluntary or involuntary. This property, as stated in another place, he conceived to be possessed by muscles as muscles, independently of all nervous influence. The heart, being a muscle, enjoyed it of necessity; and the irritant, which developed it incessantly, was the blood. In evidence of this, he observes, that its contractions are always more forcible and rapid, when the blood is more abundant; and that they occur successively in the cavities of the heart as the blood reaches them. So completely did Haller assign the heart's action to this irritability, that he even denied the nerves any influence over it; resting his belief on the admitted facts,—that the heart will continue to beat after decapitation; after the division of the spinal marrow in the neck; and of the nerves distributed to the organ; and, even, after it has been entirely removed from the body. How far the opinions of this great man are correct, respecting the power of contraction residing in the heart, as he conceived it to do in other muscles, we shall inquire presently. The heart, however, is, doubtless, indirectly under the nervous influence. We see it affected in the various emotions; sometimes augmenting its action violently, at others retarding it. These circumstances have led some individuals, as Meckel, to adopt a kind

of intermediate opinion, and to regard the nervous influence as one of the conditions necessary for all muscular contraction, just as the due circulation of blood is one of those conditions; and to admit, at the same time, the separate existence of a *vis insita*. Sömmering, and Behrend have, indeed, asserted that the cardiac nerves are not distributed to the tissue of the heart, but merely to the ramifications of the coronary arteries; and hence, that these nerves are not concerned in the functions of the organ, but only in its nutrition; but this is denied by Scarpa, and by the generality of anatomists.

Although the emotions manifestly affect the heart, direct experiments exhibit but little influence over it on the part of the nerves. This, indeed, we have seen, is one of the grounds for the doctrine of Haller. Willis divided the eighth pair of nerves; yet the action of the heart persisted for days. Similar results followed the section of the great sympathetic. Magendie states, that he removed, on several occasions, the cervical ganglions, and the first thoracic; but was unable to determine anything satisfactory from the operation, in consequence of the immediate death of the animal from such extensive injury as was inevitable. He observed, however, no direct influence on the heart.

We have numerous examples of the comparative independence of the organ, as regards the encephalon. Decapitated reptiles have lived for months; and anencephalous infants, or those born with part of the brain only, have vegetated during the whole period of pregnancy, and for some days after birth. Legallois kept several decapitated mammiferous animals alive; and maintained the heart in action, (having taken the precaution to tie the vessels of the neck for the purpose of preventing hemorrhage,) by employing artificial respiration, so as to keep up the conversion of venous into arterial blood, and thus to insure to the heart a supply of its appropriate fluid. We find, too, that in fracture of the skull, in apoplexy, and in congenerous affections, the functions of the heart are the last to be arrested.

The result of his experiments led Legallois to infer, that the power of the heart is altogether derived from the spinal marrow; and he conceived, that through the cardiac nerves it is influenced by this portion of the cerebro-spinal axis, and is liable to be affected by the passions, because the spinal marrow is itself influenced by the brain. Dr. Wilson Philip has, however, shown, that the facts do not warrant the conclusions; and he has exhibited, by direct experiment, that the brain has as much influence over the motions of the heart as the spinal marrow, when the circumstances of the experiment are precisely the same. The removal of the spinal marrow, like that of the brain, if the experiment be performed cautiously and slowly, does not sensibly affect the motion of the heart,—the animal having been previously deprived of sensibility. In these experiments, the circulation ceased quite as soon without, as with, the destruction of the spinal marrow. Loss of blood appeared to be the chief cause of its

cessation; and pain would have contributed to the same effect, if the animal had been operated on, without having been previously rendered insensible.

Mr. Clift, the ingenious conservator of the Museum of the Royal College of Surgeons of London, made a series of experiments to ascertain the influence of the spinal marrow on the action of the heart in fishes, and he found, that, whether the heart be exposed or not, its action continues long after the spinal marrow and brain are destroyed, and still longer when the brain is removed without injury to its substance. Similar results were obtained by Treviranus on the frog, and by Saviole on the chick in ovo. Zinn and Ent too found, that the heart continued its action after the destruction of the cerebellum; to which Willis ascribed the heart's action.

All these facts plainly exhibit, that, although the heart is *indirectly* influenced by the brain or spinal marrow, it is not *directly* acted upon by either one or the other, and that its action can be maintained for some time, after the destruction of one or both, provided artificial respiration be kept up: but even this last agent is unnecessary; the heart will continue to beat, even after it has been removed from the body. In the case of the rattlesnake, Dr. Harlan observed the heart, torn from the body, continue its contractions for ten or twelve hours. In the monstrous fœtus, observed by Dr. T. Robinson, its motion continued for some time after the auricles and ventricles had been laid open; the organ roughly handled, and thrown into a basin of cold water.

We are compelled, then, if we do not admit the whole of the Hallerian doctrine of irritability, to presume, that there is something inherent in the structure of the heart, which enables it to contract and dilate, when appropriately stimulated; and it is not even necessary, that this should be by the fluid, to which it is habituated. It is certain, that the organ, when separated from the body, may be stimulated to contraction, by being immersed in warm water, or pricked with a sharp-pointed instrument. In some experiments by Sir B. Brodie, he emptied the heart of its blood, and found that it still contracted and relaxed alternately. Similar experiments were instituted by Mr. Mayo, and with like results, from which he concluded, that the alternations of contraction and relaxation in the heart depend upon something in its structure. The conclusion is, indeed, irrefutable, if we add to these evidences the results of some experiments by Dr. J. K. Mitchell, of Philadelphia. In 1823, being engaged in dissecting a sturgeon—*Acipenser brevirostrum?*—its heart was taken out and laid on the ground, and, after a time, having ceased to beat, was inflated with the breath, for the purpose of drying it. Hung up in this state, it began again to move, and continued for ten hours to pulsate regularly, though more and more slowly; and, when last observed in motion, the auricles had become so dry as to rustle when they contracted and dilated. He subsequently repeated the experiment with the heart of a *Testudo serpentaria* or *snapper*, and found

it to beat well under the influence of oxygen, hydrogen, carbonic acid, and nitrogen, thrown into it in succession. Water also stimulated it,—perhaps more strongly, but made its substance look pale and hydropic, and, in *one minute*, destroyed action beyond recovery.

The heart is the generator of one of the forces that move the blood. This force has been the subject of much calculation, but the results have been so discordant as to throw discredit upon all mathematical investigations on living organs, a circumstance which renders it unnecessary to state the different plans that have been pursued in these estimations. They are all given in the elaborate *Elementa* of Haller, to which the reader, who may be desirous of examining them, is referred. Borelli conceived the force exerted by the left ventricle to be equivalent to 180,000 pounds; Senac to 40 pounds; Hales to 51 pounds 5 ounces; Jurin to 15 pounds 4 ounces; whilst Keil conceived it not to exceed from 5 to 8 ounces!

The mode, adopted by Hales, has always been regarded the most satisfactory. By inserting a glass tube into the carotid of various animals, he noticed how high the blood rose in the tube. This he found to be, in the dog, 6 feet 8 inches; in the ram, 6 feet 5½ inches; in the horse, 9 feet 8 inches; and he estimated, that, in man, it would rise as high as 7½ feet. Now a tube, whose area is one inch square and two feet long, holds nearly a pound of water. We may, therefore, reckon the weight, pressing on each square inch of the ventricle, to be, on a rough estimate, three pounds and three-quarters, or four pounds; and if we consider, with Michelotti, the surface of the left ventricle to be fifteen square inches, it will exert a force, during its contraction, capable of raising sixty pounds. Its extent is more frequently, however, estimated at 10 square inches, and the force developed will therefore be forty pounds; but this is, of course, a rude approximation. In such a deranging experiment, the force of the heart cannot fail to be modified; and it is so much affected by age, sex, temperament, idiosyncrasy, &c. that the attainment of accurate knowledge on the subject is impracticable.

2. *Circulation in the arteries.*—The blood, expelled from the heart by the series of actions we have described, enters the two great blood-vessels;—the *pulmonary artery* from the right ventricle, and the *aorta* from the left; the former of which sends it to the lungs, the latter to every part of the system; and, in both vessels, it is prevented from returning into the corresponding ventricle by the depression of the semilunar valves. We have now to inquire into the circumstances, which act upon it in the arteries, or whether it is the contraction of the ventricle, which is alone concerned in its progression.

Harvey and the whole of the mechanical physiologists regarded the arteries as entirely passive in the circulation, and as acting like so many lifeless tubes; the heart being, in their view, the sole agent in the circulation. We have, however, numerous reasons for believing, that the arteries are concerned, to a certain degree, in the

progression of the blood. If we open a large artery, in a living animal, the blood flows in distinct pulses; but this effect gradually diminishes as the artery recedes from the heart, and ultimately ceases in the smallest arterial ramifications;—seeming to show, that the force, exerted by the heart, is not the only one concerned in propelling the blood through these vessels. It is manifest, too, that if the action of the heart were alone concerned, the blood ought to flow out of the aperture, when the artery is opened, at intervals coinciding with the contractions of the heart; and that during the diastole of the artery, no blood ought to issue. This, however, is not the case, notwithstanding the authority of Bichat, and some others is in its favour. The flow is not uninterrupted, but in jets or pulses, coinciding with the contractions of the ventricles.

Again, if two ligatures be put round an arterial trunk, at some distance from each other, and a puncture be made between the ligatures, the blood flows with a jet, indicating that compression is exerted upon it; and if the diameter of the artery be measured with a pair of compasses, before and after the puncture, it will be found manifestly smaller in the latter case;—an experiment, which shows the fallacy of a remark of Bichat,—that the force with which the arteries return upon themselves is insufficient to expel the blood they contain. An experiment of Magendie exhibits this yet more clearly. He exposed the crural artery and vein in a dog, and passed a ligature behind the vessels, tying it strongly at the posterior part of the thigh, so that the blood could only pass to the limb by the artery, and return by the vein. He then measured, with a pair of compasses, the diameter of the artery; and, on pressing the vessel between his fingers, to intercept the course of blood in it, the artery was observed to diminish perceptibly in size below the part compressed, and to empty itself of the blood it contained. On readmitting the blood, by removing the fingers, the artery became gradually distended at each contraction of the heart, and resumed its previous dimensions.

These facts prove, that the arteries contract; but the kind of contraction has given occasion to much discussion. It has been imagined, by some physiologists, that their proper coat is muscular, and that they exert a similar action on the blood to that of the heart; dilating to receive it from that organ, and contracting to propel it onwards;—their systole being synchronous with the systole of the auricles and the diastole of the ventricles, and their diastole with that of the auricles, and the systole of the ventricles. The principal reasons, urged in favour of this view, are;—the fact of the circulation being effected solely by the arteries in acardiac fœtuses, and in animals which have no heart;—the assertion of MM. Lamure and Lafosse, that they noticed, in the experiment with the carotid artery, described above, that the vessel continued to beat between the ligatures;—the affirmations of Verschuir, Bekker, Giulio, and Rossi, Thomson, Parry, Hastings, Wedemeyer, and numerous

others, that when they irritated arteries with the point of a scalpel or subjected them to the electrical and galvanic influences, they exhibited manifest irritability; and lastly, the questionable fact, that the pulse is not perfectly synchronous in different parts of the body, which ought to be the case, were the arteries not possessed of any distinct action.

The chief objection to the views, founded on the muscularity of the middle coat, is the want of evidence of the fact. In the anatomical proem to the function of the circulation, it was stated, that this coat does not seem to consist of the fibrous or muscular tissue; and that the experiments of Magendie, Nysten, and others, had not been able to exhibit any contraction, on the application of the ordinary excitants of muscular irritability. The chymical analyses of Berzelius and Young also show, that the transverse fibres differ essentially from proper muscles.

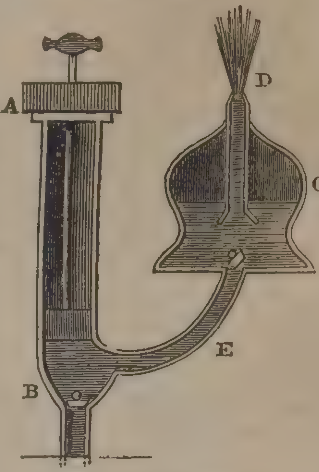
Again, if an artery be exposed in a living animal, we observe none of that contraction and dilatation which is perceptible in the heart; although a manifest pulsation is communicated to the finger placed over it. The phenomena of the pulse will engage attention speedily. We may merely remark, at present, that the pulsations are manifestly more dependent upon the action of the heart than upon that of the arteries. In syncope, they entirely cease; and whilst they continue beneath an aneurismal tumour, because the continuity of the vessel is not destroyed, they completely cease beneath a ligature, so applied round an artery as to cut off the flow of blood. Bichat attached an inert tube to the carotid artery of a living animal, so that the blood could flow through it: the same kind of pulsation was observed in it as in the artery. To this he adapted a bag of gummed taffeta, so as to simulate an aneurismal tumour: the pulsations were evidenced in the bag. If, again, arterial blood be passed into a vein, the latter vessel, which has ordinarily no pulsation, now begins to beat; whilst, if blood from a vein be directed into an artery, the latter ceases to beat.

Another class of physiologists have reduced the whole of the arterial action to simple elasticity; a property, which the yellow tissue that composes the proper membrane of the artery, seems to possess to an unusual degree. Such is the opinion of Magendie. "Admitting it to be certain," he remarks, "that contraction and dilatation occur in the arteries, I am far from thinking, with some authors of the last century, that they dilate of themselves, and contract in the manner of muscular fibres. On the contrary, I am certain, that they are passive in both cases, that is, that their dilatation and contraction are the simple effect of the elasticity of their parietes, put in action by the blood, which the heart sends incessantly into their cavity;—and he farther remarks, that there is no difference, in this respect, between the large and the small arteries.

As regards the larger arteries, it is probable, that this elasticity is the principal but not the only action exerted; and that it is the cause,

why the blood flows in a continuous, though pulsatory, stream, when an opening is made into them; thus acting, as Magendie has suggested, like the reservoir of air in certain pumps. In the pump A B, represented in the marginal figure, were there no air-vessel C, the water would flow through the pipe E at each stroke of the piston, but the stream would be interrupted. By means of the air-vessel, this is remedied. The water, at each stroke, is sent into the vessel; the air contained in the air-vessel is thus compressed, and its elasticity thereby augmented; so that it keeps up a constant pressure on the surface of the water, and forces it out of the vessel, through the pipe D, in a nearly uniform stream. Now, in the heart, the contraction of the ventricle acts like the depression of the piston; the blood is propelled into the artery in an interrupted manner, but the elasticity of the blood-vessel presses upon the blood, in the same manner as the air, in the air-vessel, upon the water within it; and thus the blood flows along the vessel in an uninterrupted, although pulsatory, stream.

Fig. 128.



Section of a forcing pump.

There are many difficulties, however, in the way of admitting the whole of the action of the arteries in the circulation to be dependent upon simple elasticity. The heart of a salamander was opened by Spallanzani, yet the blood continued to flow through the vessels for twelve minutes after the operation. The heart of a tadpole was cut out, yet the circulation was maintained for some time in several of the vascular ramifications of the tail. The heart of the chick in ovo was destroyed immediately after contraction; the arterial blood took a retrograde direction, and the momentum of the venous blood was redoubled. The circulation continued in this manner for eighteen minutes. Dr. Wilson Philip states, that he distinctly saw the circulation in the smaller vessels, for some time after the heart had been removed from the body, and a similar observation was made by Dr. Hastings. The latter gentleman states, that in the large arterial trunks, and even in the veins, he has noticed, in the clearest manner, their contraction on the application of various stimulants, both chymical and mechanical. It is, moreover, well known, that if a small living artery be cut across, it will soon contract, so as to arrest hemorrhage; and that, whilst an animal is bleeding to death, the arteries will accommodate themselves to the decreasing quantity

of blood in the vessels, and contract beyond the degree to which their elasticity could be presumed to carry them; and that after death they will again relax. Dr. Parry found, that the artery of a living animal, if exposed to the air, will sometimes contract in a few minutes to a great extent; in such case, only a single fibre of the artery may be affected, narrowing the channel in the same way as if a thread were tied round it.

The experiments which have been instituted for the purpose of discovering the dependence of the arterial action on the nervous system, have likewise afforded evidences of their capability of assuming a contractile action, and have led to a better comprehension of those cases of what have been called local *determinations* of blood. Dr. Philip found, that the motion of the blood in the capillaries is influenced by stimulants, applied to the central parts of the nervous system, which must be owing to the capillaries possessing a power of contractility, capable of being aroused to action by the nervous influence. The experiments of Sir Everard Home are, however, more applicable, as having been directed to the larger arteries, respecting which the greatest doubts have been entertained.

The carotid artery of a dog was laid bare; the par vagum and great sympathetic, which, in that animal, form one bundle, were separated from it by a flattened probe, for one-tenth of an inch in length; the head and neck of the dog were then placed in an easy position, and the pulsations of the carotid artery were attended to by all present, for two minutes, in order that the eye might be accustomed to their force in a natural state. The nerve, passing over the probe, was then slightly touched with caustic potassa. In a minute and a half, the pulsations of the exposed artery became more distinct. In two minutes, the beats were stronger; in four minutes, their violence was lessened; and in five minutes, the action was restored to its natural state. The experiment was repeated, with analogous results, upon a rabbit. In that animal, the par vagum was separated from the intercostal nerve; and it was found, that, when the par vagum alone was irritated, no increase took place in the force of the action of the artery. "The carotid artery," says Sir Everard, "was chosen as the only artery in the body of sufficient size, that can be readily exposed, to which the nervous branches, supplying it, can be traced from their trunk. This experiment was repeated three different times, so as to leave no doubts respecting the result." These experiments demonstrate, that, under the nervous influence, an increase or diminution can take place in the contraction of an artery; and they aid us in the explanation of those cases, in which the circulation has been accomplished, where the heart has been altogether wanting or completely defective in structure.

Sir Everard instituted some farther experiments, with the view

of determining whether heat or cold has the greatest agency in stimulating the nerves to produce this effect upon the artery. The wrist of one arm was surrounded by bladders filled with ice; and after it had remained in that state for five minutes, the pulse of the two wrists was felt at the same time. The beats in that which had been cooled, were found to be manifestly stronger. A similar experiment was now made with water, heated to 120° or 130° of Fahrenheit. The pulse was found to be softer and feebler in the heated arm. When one wrist was cooled and the other heated, the stroke of the pulse, in the cooled arm, had much greater force than that of the heated one.

These experiments were repeated upon the wrists of several young men and young women of different ages, with a uniform result.

Lastly, we have remarked, and shall have occasion to refer to the matter again, that certain animals, which have no heart, have circulating vessels in which contraction and dilatation are perceptible. This is the case with the class *vermes* of Cuvier, and can be seen very distinctly in the *lumbricus marinus* or *lug*, the *leech*, &c. The fact has been invoked by the believers in the muscular contractility of arteries, as well as by those who conceive the contractility to be peculiar; but our acquaintance with the intimate structure of the coats of the vessels, in those animals, is too minute for us to assert more, than that they are manifestly contractile.

From these and other considerations, the majority of physiologists, amongst whom we may mention Haller, Whytt, Senac, Cullen, Stahl, Von Gorter, Hunter, Wilson Philip, Parry, Thomson, Hastings, Bostock, Marshall Hall, and Adelon, have admitted a contractile action, not simply in the capillary vessels, but in the larger arterial trunks; and, at the present day, the most general and satisfactory opinion appears to be, that, in addition to the highly elastic property possessed by the middle coat, it is capable of being thrown into contraction; that, in the larger vessels, this contraction is rarely exerted, the action of the artery being simply produced by its elasticity; but that, in the smaller arterial ramifications, the contractility is more apparent; and, in the capillary vessels, is scarcely equivocal. To this action of contractility, necessarily connected with the life of the vessel, and differing from both muscular contractility and simple elasticity, Dr. Parry gave the name *tonicity*.

3. *Circulation through the capillaries.*—The agency of the capillary vessels in the circulation has been a subject of contention. It was the opinion of Harvey, that the action of the heart is alone sufficient to send the blood through the whole circuit; but we have seen, that, even when aided by the elasticity and contractility of the arterial trunks, the pulsations of the heart become imperceptible in the smaller arteries; and, hence, that there is some show of reason for the belief, that, in the capillary vessels, the force may be entirely spent. Such, indeed, is the opinion of Bichat, who regards the capillaries as organs of propulsion, and alone concerned in returning

the blood to the heart through the veins. Dr. Marshall Hall, on the other hand, denies that we have any proof of irritability in the true capillaries; and, again, Magendie conceives the contraction of the heart to be the principal cause of the passage of the blood through these vessels. In support of this view he adduces the following experiment. Having passed a ligature round the thigh of a dog, so as not to compress the crural artery or vein, he tied the vein near the groin, and made a small opening into the vessel. The blood immediately issued with a considerable jet. He then pressed the artery between the fingers, so as to prevent the arterial blood from passing to the limb. The jet of venous blood did not, however, stop. It continued for some moments, but went on diminishing, and the flow was arrested, although the vein was filled throughout its whole extent. When the artery was examined during these events, it was observed to contract gradually, and at length became completely empty when the course of the blood in the vein ceased. At this stage of the experiment, the compression was removed from the artery; the blood immediately passed into the artery, and, as soon as it had reached the final divisions, it began to flow again through the opening in the vein, and the jet was gradually restored. On compressing the artery again, until it was emptied, and afterwards allowing the arterial blood to pass slowly along the vessel, the discharge from the vein occurred, but without any jet; which was resumed, however, as soon as the artery was entirely free.

This experiment is not so convincing as it appears to be to M. Magendie. The chief fact, which it exhibits, is the elastic, and probably contractile, power of the arteries. It might have been expected, *a priori*, under any hypothesis, that the quantity of blood discharged from the vein would hold a ratio with that sent by the arteries; and,. consequently, the experiment appears to us to bear but little on the question regarding the separate contractile action of the capillaries. It is difficult, indeed, to believe, that such an action does not exist. In addition to the circumstance, already mentioned, of the absence of pulsation in the smaller arteries, almost every writer on the theory of inflammation considers the fact of a distinct action of the capillaries established, and leaves to the physiologist the by no means easy task of proving it. Dr. Wilson Philip placed the web of the frog's foot in the microscope, and distinctly saw the capillaries contract upon the application of those stimulants, which produce contraction of the muscular fibre. The result of Dr. Thomson's experiments, in investigating the subject of inflammation, were the same, as well as those of Dr. Hastings. The facts, which we have already referred to, regarding the continuance of the circulation in the minute vessels, after the heart has been removed, are confirmatory of the same point; as well as the observation of Dr. Philip, that the blood in the capillaries is influenced by stimulants applied to the central parts of the nervous system. The experiments of Thomson and Philip and Hastings were repeated by

Wedemeyer, with great care. The circulation of the mesentery of the frog, and in the web of its foot, being observed through the microscope, it was evident, that no change occurred in the diameter of the small arteries, or in that of the capillaries, so long as the circulation was allowed to go on in its natural state; but as soon as excitants were applied to them, an alteration of their calibre was perceptible. Alcohol arrested the flow of blood without inducing much apparent contraction of the vessels. Chloride of sodium, in the course of three or four minutes, caused the vessels to contract one-fifth of their calibre, which contraction was followed by dilatation of the vessels, and a gradual retardation and stoppage of the blood. In a space of time varying from ten to thirty seconds, and sometimes immediately after the application of the galvanic circle, the vessels contracted, some one-fourth, others one-half, and others three-fourths of their calibre. The contraction sometimes continued for a considerable time, occasionally several hours; in other instances, it ceased in ten minutes, and the vessels resumed their natural diameter. A second application of galvanism to the same capillaries seldom caused any material contraction.

All these facts prove the existence of a vital power in the capillaries, capable of modifying, to a considerable extent, the flow of blood through them.

Again, of this independent action of the capillary vessels we have, every day, proofs in local inflammation; in which there is increased redness of a part, without the general circulation exhibiting the slightest evidences of augmented action or excitement. In the natural state, the tunica conjunctiva, covering the white of the eye, is not supplied with red vessels; but if any cause of irritation exist, as a grain of sand entering between the eyelids, we find red blood rapidly sent into the white vessels, giving the appearance, which has been termed, not inappropriately, "bloodshot." In the experiments of Kaltenbrunner, which were fully confirmed on repetition, the blood was at first observed, in inflammation, streaming to the irritated part, in consequence of which the capillary vessels became distended; afterwards irregularity of circulation occurred in the gorged capillary system; and subsequently complete arrestation of the circulation, and disorganization.

These phenomena are of themselves sufficient to prove the existence of the separate action of the capillaries, and, when taken in conjunction with other facts, are overwhelming. The blush of modesty, and the paleness of guilt, the hectic glow, and the translucency of congelation, are all circumstances, that go to establish the same point.

This contractile power of the capillaries is doubtless modified by the condition of the ganglionic nerves distributed to them, which, as we have seen, are observed to increase as the size of the vessels and the thickness of their coats diminish. Their influence is, indeed, strikingly evinced in actions, which are altogether nervous, as in

the flushed countenance occasioned by sudden mental emotions. By some, however, the whole capillary circulation has been ascribed to the motive faculty inherent in the globules of the blood; whilst others, again, have asserted, that the electro-galvanic power, —or in other words—the nervous power, generated in the nervous system, and acting through it on the blood globules in the capillary system, is the immediate agent directing the movements or circulation in the capillaries: all this, however, enters into the inscrutable question of what is the cause of life in the fluids or tissues,—a question to be agitated, but not solved, in a subsequent part of this volume.

But not only has a vital power of contraction been conceded to the capillaries; it has been imagined, that they possess what the Germans call a lebensturgor (turgor vitalis), or vital property of expansibility. Such appears to be the opinion of Hebenstreit and of Pruss; and it has been embraced, in this country, by Professor Smith of Yale College; by his son, Professor N. R. Smith, of the University of Maryland, in his excellent work on the "Surgical Anatomy of the Arteries," and by Dr. Hodge of Philadelphia. The idea has been esteemed to be confirmed by the fact of excitants having been seen under the microscope, by Hastings, Wedemeyer, and others, to occasion not only contraction but dilatation of the capillaries. The phenomena, observed in the erectile tissues, have likewise been considered to favour the hypothesis; but, in answer to these arguments, it may be replied, that the irregular excitation, produced in the parts by the application of powerful stimulants, might readily give occasion to an appearance of expansibility under the microscope, without our being justified in inferring, that these vessels possess an innate vital property of expansibility; and, in many of these cases, in which ammonia and galvanism were applied by Thomson, Hastings, Wedemeyer and others, the action of contraction ought rather, as J. Müller has suggested, to be esteemed physical or chemical, than vital. The results of the application of such excitants, as of diluted alcohol, dilute solutions of ammonia and of chloride of sodium can alone be invoked as evidences of vital action on the part of these vessels; and the dilatation of the capillary system and of the smaller arteries, which has been remarked on the contact of these agents, is not, as Österreicher has remarked, the primary effect. It is the consequence of the afflux of blood to the irritated part, as is also demonstrated in the experiments of Kaltenbrunner on inflammation, to which allusion has been made. Lastly, attentive observation of the phenomena presented by the erectile tissues must lead to the conclusion, that the turgescence of the vessels is not the first link in the chain of phenomena; excitation is first induced in the nerves of the part—generally through the influence of the brain—and the afflux of fluid supervenes on this.

The vital expansibility of the capillaries cannot then, we think, be regarded as either proved or probable.

It is in this part of the sanguiferous system, that most important functions take place. In the smallest artery, we find arterial blood; and in the smallest vein, communicating with it, blood always possessing the venous properties. Between those points, a change must have occurred, precisely the reverse of that which happens in the lungs. It is in this very part, too, that nutrition, secretion, and calorification are effected. In the explanation of these functions, we shall find it impossible not to invoke a distinct and elective agency in the tissues concerned; and as it is by such agency, that the varying activity of the different functions is regulated, we are constrained to believe, that the capillary vessels may be able to exert a controlling influence over the quantity and velocity of the blood circulating in them.

In disease, the agency of this system of vessels is an object of attentive study with the pathologist. To its influence in inflammation, we have already alluded; but it is no less exemplified in the more general diseases of the frame,—as in the cold, hot, and sweating stages of an intermittent. Local, irregular capillary action is, indeed, one of the most common causes of acute affections, and these generally occur in some organ, at a distance from the seat of the deranging influence. It is a common and just observation, that getting the feet wet, and sitting in a draught of air, are more certain causes of catarrh than sudden atmospheric vicissitudes, which necessarily apply to the whole body; and so extensive is the sympathy between the various portions of this system of vessels, that the most diversified effects will be produced in different individuals exposed to the same common cause; one may have inflammatory sore throat; another, ordinary catarrh; another, inflammation of the bowels; according to the precise predisposition, existing in the individual at the time, to have one structure morbidly affected rather than another. These are interesting topics, but they belong more strictly to the pathologist.

By the united action, then, of the heart, the arteries, and the capillary system of vessels, the blood attains the veins. We have now to consider the circulation in those vessels.

4. *Circulation in the veins.*—It has been already observed, that Harvey considered the force of the heart to be of itself sufficient to return the blood, sent from the left ventricle, to the heart; whilst Bichat conceived the whole propulsory effort to be lost in the capillaries and the transmission of the blood along the veins to be entirely effected by the agency of the capillary system. It is singular, that an individual, of such distinguished powers of discrimination, should have been led into an error of such magnitude. It is a well-known principle in hydrostatics, that although water, when unconfined, can never rise above its level, at any point, and can never move upwards; yet, by being confined in pipes or close channels of any kind, it will rise to the height from which

it came. Hence the water or blood in the vessel A, Fig. 129, which may be considered to represent the right auricle, would stand at the same height as that in the vessel B, which we may look upon as the left ventricle, were they even inanimate tubes. We need be at no loss, therefore, in understanding how the blood might attain the right auricle by this hydrostatic principle alone; but we have seen that, to this, the force exerted by the heart, by the arteries, and by the capillary system is superadded, so that the blood would rise much higher than the right auricle, and consequently exert a manifest effort to enter. It may be remarked, also, that the left ventricle is not the true height of the source, but the top of the arch of the aorta, which is more elevated, by several inches, than the right auricle.

Fig. 129.

Are we then to regard the veins as simple elastic tubes? This is the prevalent belief. Their elasticity is, however, much less than that of the arteries. Some physiologists have conceived them to possess contractile properties. Such is the opinion of Broussais, who founds his opinion, in part, upon certain experiments by Sarlandière, already referred to, in which contraction and relaxation of the vena cava of a frog were seen, for many minutes after the heart was removed from the body. In the experiments of Dr. Marshall Hall, on the circulation in the web of the frog's foot, he was almost invariably able to detect, with a good microscope, a degree of pulsatory acceleration of the blood in the arteries at each contraction of the heart, and he is disposed to conclude, from his observations, that the natural circulation is rapid, and entirely pulsatory in the minute arteries, and slow and equable in the capillary and venous systems. But whenever the circulation was in the slightest degree impeded, the pulsatory movement became very manifest at each systole of the heart, when it was seen in all the three systems of vessels—arterial, capillary, and venous. He observed, that in the arteries there was generally an alternate, more or less rapid, flow of the globules at each systole and diastole of the heart: that in the capillaries and veins the blood was often completely arrested during the diastole, and again propelled by a pulsatory movement during the systole of that organ; all which he esteems conclusive proof, that the power and influence of the heart extend through

the arteries to the capillaries, and through these to the veins, even in the extreme parts of the body.

That the veins are possessed of elasticity is proved by the operation of blood-letting, in which a part of the jet, on puncturing the vein, is owing to the over-distended vessel returning upon itself; but, that this property exists to a trifling extent only, is shown by the varicose state of the vessels, which so frequently occurs in the lower extremities.

From this inquiry into the agency of the different circulatory organs in propelling the blood, it is manifest, that the action of the heart; the elasticity of the arteries, and a certain degree of contractile action, in the smaller vessels more especially, a distinct action of the capillary vessels, and a slight elastic and perhaps contractile action on the part of the veins must be chiefly invoked. Of these, the action of the heart, and capillaries, and the contraction of the arteries and veins, can alone be regarded as sources of motion, the elasticity of the vessels being simple directors, not generators of force. But there is another agency, which is doubtless, far more efficient than has generally been conceived. This is the *suction power* of the heart, or *derivation*, as it has been termed, to which attention has been chiefly directed by Haller, Wilson Philip, Carson, Zugenbühler, Schubarth, Platner, Blumenbach and others. It is presumed, that the muscular fibres of the heart are mixed up with a large quantity of cellular tissue; and that, whilst the contraction of the cavities is effected by the action of the muscular fibres, dilatation is produced by the relaxation of the contracted fibres, and the elasticity of the cellular tissue; so that when the heart has contracted, and sent its blood onwards, its elasticity instantly restores it to its dilated condition; a vacuum is formed, and the blood rushes in to fill it. This action has been compared, by Dr. Bostock, and by Sir Charles Bell, to that of an elastic gum bottle, which, when filled with water, and compressed by the hand, allows the fluid to be driven from its mouth with a velocity, proportionate to the compressing force. But the instant the pressure is removed elasticity begins to operate, and if the mouth of the bottle be now immersed in water, a considerable quantity of that fluid will be drawn up into the bottle, in consequence of the vacuum formed within it. The existence of this force is confirmed by Döllinger,—who, when examining the embryo of birds, saw the blood advance along the veins, whilst the venous trunks poured it into the auricles at the moment when they dilated to receive it; as well as by Dr. T. Robinson, who was forcibly struck with the activity with which the diastole was effected, in the case of monstrosity, more than once referred to.

Another accessory force, which has been invoked, is the suction power of the chest, or the *inspiration of venous blood*, as it has been termed. This is conceived to be effected by the same mechanism as that which draws air into the chest. The chest is

dilated during inspiration; an approach to a vacuum occurs in the thorax; and the blood, as well as the air, is forcibly drawn towards that cavity. On the other hand, during expiration, all the thoracic viscera are compressed; the venous blood is repelled from the chest, whilst the arterial blood reaches its destination with greater celerity, owing to the action of the expiratory muscles being added to that of the left ventricle.

Haller, Lamure, and Lorry had observed, that the blood, in the external jugular vein, moves under manifestly different influences, during inspiration and expiration. Generally, when the chest is dilated in inspiration, the vein empties itself briskly, becomes flat, and its sides are, occasionally, accurately applied against each other; but, during expiration, the vein rises and becomes filled with blood;—effects, which are more evident, when the respiratory movements are more extensive. The explanation of this phenomenon, by Haller and Lorry, is the one given above.

To discover whether the same thing happens to the venæ cavæ, Magendie introduced a gum elastic catheter into the jugular vein, so as to penetrate the vena cava and even the right auricle;—the blood was observed to flow from the extremity of the tube at the time of expiration only. During inspiration, air was rapidly drawn into the heart, giving rise to the symptoms, to be mentioned hereafter, which attend the reception of air into that organ. Similar results were obtained, when the tube was introduced into the crural vein in the direction of the abdomen. So far as regards the larger venous trunks, therefore, the influence of respiration on the circulation is sufficiently evidenced.

It can be easily shown, by opening an artery in the limbs, that expiration manifestly accelerates the motion of arterial blood; especially in forced expiration, and during violent exertion. In animals, subjected to experiment, it is impracticable to excite either the forced expiration or the violent effort at pleasure; but we can, as a substitute, compress the sides of the chest with the hands, according to the plan recommended by Lamure, when the blood will be found to flow more or less copiously, in proportion to the pressure exerted.

It occurred to Magendie, that this effect of respiration on the course of the blood in the arteries might influence the flow along the veins. To prove this, he passed a ligature round one of the jugular veins of a dog. The vessel emptied itself beneath the ligature, and became turgid above it. He then made a slight puncture, with a lancet, in the distended portion; and in this way obtained a jet of blood, which was not sensibly modified by the ordinary respiratory movements, but became of triple or quadruple the size, when the animal struggled. As it might be objected to this experiment, that the effect of respiration was not transmitted by the arteries to the open vein, but rather by the veins that had remained free, which might have conveyed the blood—repelled from the vena cava—towards the tied vein, by means of anastomoses,—the experi-

ment was varied. The dog has not, like man, large internal jugular veins, which receive the blood from the interior of the head. The circulation from the head and neck is, in it, almost wholly confined to the external jugular veins, which are extremely large; the internal jugulars being little more than *vestiges*. By tying both of these veins at once, Magendie made sure of obviating, in great part, the reflux in question; but, instead of this double ligature diminishing the phenomenon under consideration, the jet became more closely connected with the respiratory movements; for it was manifestly modified even by ordinary respiration, which was not the case when a single ligature was employed.

From these and other experiments, Magendie properly concludes, that the turgescence of the veins must not be ascribed, with Haller, Lamure, and Lorry, simply to the reflux of the blood of the venæ cavæ into the branches opening directly or indirectly into them; but that it is partly owing to the blood being sent in larger quantity into the veins from the arteries.

In the same manner are explained—the rising and sinking of the brain, which, as was observed in an early part of this work, are synchronous with expiration and inspiration. During expiration, the thoracic and abdominal viscera are compressed; the blood is driven more into the branches of the ascending aorta, and it is, at the same time, prevented from returning by the veins: owing to the combination of these causes, the brain is raised during expiration. In inspiration, all this pressure is removed; the blood is free to pass equally by the descending, as by the ascending, aorta; the return by the veins is ready, and the brain therefore sinks.*

We can thus, also, explain why the face is red and swollen during crying, running, straining, and the violent emotions; and why pain is augmented in local inflammations of an extremity,—as in cases of whitlow,—when respiration is hurried or impeded by running, crying, &c. The blood accumulates in the part, owing to the compound effect of increased flow by the arteries, and impeded return by the veins. The same explanation applies to the production of hemorrhage by any violent exertion; and Bourdon affirms, that he has always seen hemorrhage from the nose largely augmented during expiration; diminished at the time of inspiration, and arrested by prolonged inspiration;—a therapeutical fact of some interest.

It is manifest, then, that the circulation is modified by the movements of inspiration and expiration,—the former facilitating the flow of blood to the heart by the veins, and the latter encouraging the flow by the arteries; and we shall see hereafter, that there is great reason for the belief, that the dilatation of the chest,—which

* This motion of the brain must not be confounded with that which is synchronous with the contraction of the left ventricle; and which is owing to the pulsation of the arteries at the base of the brain.

constitutes the first inspiration of the new-born child,—is a great cause of the establishment of the new circulation; the same dilatation, which causes the entrance of air into the air-cells, soliciting the flow of blood, or the "inspiration of venous blood," as Magendie has termed it.

The influence of ordinary respiration can, however, be but trifling; yet it has been brought forward by Dr. Barry as the efficient cause of venous circulation. His reasons for this belief are,—the facts just mentioned, regarding the influence of inspiration on the flow of blood towards the heart, and certain ingeniously modified experiments, tending to the elucidation of the same result. He introduced one end of a spirally convoluted tube into the jugular vein of an animal, and plunged the other into a vessel filled with a coloured fluid. During inspiration, the fluid passed from the vessel into the vein; during expiration, it remained stationary in the tube, or was repelled into the vessel. Dr. Bostock remarks, that he was present at some experiments, which were performed by Dr. Barry himself at the Veterinary College in London, and it appeared sufficiently obvious, that when one end of a glass tube was inserted either into the large veins, into the cavity of the thorax, or into the pericardium, —the other end being plunged into a vessel of coloured water,—the water was seen to rise up the tube during inspiration, and to descend during expiration.

The conclusion of Dr. Barry, from these experiments, is most comprehensive;—that "the circulation in the great veins depends upon atmospheric pressure in all animals possessing the power of contracting and dilating a cavity around that point, to which the centripetal current of their circulation is directed;" and he conceives, that as, during inspiration, a vacuum is formed around the heart, the equilibrium of pressure is destroyed, and the atmosphere acts upon the superficial veins, propelling their contents onwards to supply the vacuum.

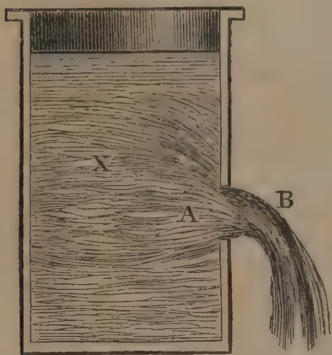
Independently of other objections, there are a few, which appear to us convincing against this sole agency of ordinary respiration in effecting venous circulation. According to Barry's hypothesis, blood ought to arrive at the heart at the time of inspiration only; and as there are, in the average, seventy-two contractions of the heart for every eighteen inspirations; or four contractions, or—what is the same thing—four dilatations of the auricle for each respiration; one of these only ought to be concerned in the propulsion of blood, whilst the rest should be bloodless; yet we feel no difference in the strength of the four pulsations. It is clear, too, if we adopt Dr. Barry's reasoning, that, of the four pulsations, two, and consequently two dilatations of the auricles, must occur during expiration, at which time the capacity of the chest is actually diminished. Moreover, holding the breath ought to suspend the circulation. It is manifest, too, that the respiratory influence cannot be invoked to explain the circulation in the fœtus or in aquatic animals.

At the most, therefore, the influence of respiration can only be regarded as a feeble auxiliary in the circulation. In favour of Dr. Barry's opinion of the efficiency of atmospheric pressure in causing the return of blood by the veins, he adduces the fact,—already referred to, under the head of *Absorption*,—that the application of an exhausted vessel over a poisonous wound prevents the absorption of the poison; but this, as we have seen, appears to be a physical effect, which would apply equally to any view of the subject.

In all these cases, the elastic resilience of the lungs, by contributing to diminish the atmospheric pressure upon the outer surface of the auricles, may, as suggested by Dr. Carson, have some agency in soliciting the blood into those cavities, but the agency cannot be great.

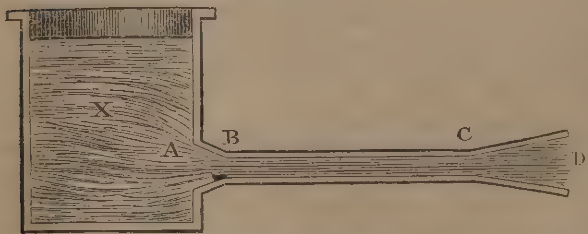
There is another circumstance of a purely physical nature, which may exert some influence upon the flow of the blood along the veins; viz. the expanded termination of the venæ cavæ in the right auricle. To explain this, it is necessary to premise a detail of a few hydraulic facts. If an aperture A, Fig. 130, exist in a cistern X, the water will not issue at the aperture by a stream of uniform size; but, at a short distance from the reservoir, it will be contracted as at B, constituting what has been termed the *vena contracta*. Now, it has been found, that if a tube, technically called an *adjutage*, be attached to this aperture, so as to accurately fit the stream, as at A B, Fig. 131, as much fluid will flow from the reservoir as if the aperture alone existed.

Fig. 130.



Again, if the pipe B C be attached to the adjutage A B, the expanded extremity at A will occasion the flow of water, from the reservoir, to be greater than it would be, if no such expanded extremity existed, in the ratio, according to Venturi, of 12.1 to 10; and if to the tube B C, a truncated conical tube C D be attached, the length of which is nearly nine times the diameter of C; and the diameter of C to that of D be as 1 to 8; the flow of water will be augmented in the proportion of 24 to 12.1; so

Fig. 131.



that, by the two adjutages A B and C D, the expenditure through the pipe B C is increased in the ratio of 24 to 10.

This fact,—the result of direct experiment, and so important to those who contract to supply water by means of pipes,—was known to the Romans. Private persons, according to Frontinus, were in the habit of purchasing the right of delivering water in their houses from the public reservoirs, but the law prohibited them from making the conducting pipe larger than the opening allowed them in the reservoir, within the distance of fifty feet. The Roman legislature must, therefore, have been aware of the fact, that an adjutage with an expanded orifice would increase the flow of water; but they were ignorant, that the same effect would be induced beyond the fifty feet.

Let us apply this law to the circulation. In the first place, at the origin of the pulmonary artery and aorta, there is a manifest narrowness, formed by the ring at the base of the semilunar valves; see Fig. 124; and this might be conceived unfavourable to the flow of the blood along these vessels during the systole of the ventricles; but from the law, which has been laid down, the narrowness would occupy the natural situation of the vena contracta, and, therefore, little or no effect would be induced. The discharge would be the same as if no such narrowness existed.

We have seen, again, that the vena cava becomes of larger calibre as it approaches the right auricle, and finally terminates in that cavity by an expanded aperture. This may have a similar effect with the expanded tube C D, Fig. 131, which doubles the expenditure.

In making these conjectures,—some of which have been invoked by Sir Charles Bell,—it is proper to observe, that, in the opinion of some natural philosophers, the effect of the adjutage is entirely due to atmospheric pressure, and that no such acceleration occurs, provided the experiment be repeated *in vacuo*. Sir Charles Bell conceives, that "the weight of the descending column in the reservoir being the force, and this operating as a *vis a tergo*, it is like the water propelled from the jet d'eau, and the gradual expansion of the tube permits the stream from behind to force itself between the filaments, and disperses them, without producing that pressure on the sides of the tube, which must take place, where it is of uniform calibre." It is on this latter view only, that these singular hydrostatic facts can be applied to the doctrine of the circulation.

In addition to the movements, impressed on the blood by the parietes of the cavities in which it moves, it has been considered by many physiologists,—as by Harvey, Glisson, Bohn, Albinus, Rosa, Tiedemann, G. R. Treviranus, Rogerson, and others,—to possess a power of self-motion. Broussais asserts, that he has seen experiments,—originally performed by P. A. Fabre, which showed, that the blood, in the capillary system, frequently moves in an opposite direction to that given it by the heart,—repeated by M. Sarlan-

dière, on the mesentery of the frog. In these, the blood was seen to rush, for some moments, towards the point irritated, and, when a congestion had taken place there, they remarked, that the globules took a different direction, and traversed vessels, which conveyed them in an opposite course, and, a few seconds afterwards, these were again observed to return with equal rapidity to the point from which they had been repelled. Tiedemann has collected the testimonies of various individuals on this point. Haller, Spallanzani, Wilson Philip, G. R. Treviranus, and others, have remarked, by the aid of the microscope, that the blood continued to move in the vessels of different animals, but chiefly of frogs, for some time after the great vessels had been tied, or the heart itself removed;—a fact which M. Tiedemann himself has often witnessed. C. F. Wolff, Döllinger and Pander, Prévost and Dumas, and others, saw globules of blood in motion in the incubated egg, before the formation of either vessels or heart; and Hunter, Gruithuisen, and Kaltenbrunner observed—in the midst of the cellular tissue of inflamed parts, in tissues undergoing regeneration, and during the cicatrization of wounds,—bloody points placed successively in contact with each other, forming small currents, which represented new vessels, and united to those already existing. The fact, indeed, that the embryo forms its own vessels, and that blood in motion can be detected before vessels are *in esse*, is a sufficient proof,—were there no other,—that the globules of the blood possess the faculty of self-motion. Still, as Tiedemann has remarked, although we admit this property; in animals provided with a heart the progression of the blood is mainly owing to that organ; for, after it ceases to act, the circulation is soon arrested. The blood, too, only remains fluid, and possesses the faculty of motion, whilst it is in connexion with the living body. When taken from the vessel in which it circulates, it soon coagulates, and loses its motive power.

Burdach has properly observed, that the old but perfectly correct saying, '*ubi stimulus, ibi affluxus*,' means nothing more than that where the vital activity of an organ is augmented, more blood will be drawn to it; whence it naturally follows, that the progression of blood in the capillaries must be, in some measure, dependent on the activity of the vital manifestations in the tissues. It has been already shown, that, if the capillary action be excited by stimulants, a greater flow of blood takes place into that system of vessels; and, as the functions of nutrition and secretion are accomplished by that system, it is obvious, that any increase in the activity of these functions must attract a larger afflux of fluids, and, in this manner, modify the circulation, independently of the heart and larger vessels. But this, again, can have but a subordinate influence on the general circulation.

Lastly, Raspail resolves the whole of the circulation, as he does every other function, into a double action of *aspiration* and *expiration* by the tissues concerned. As the blood is the bearer of life to

every part of the organism, and of nourishment and reparation to the organs,—to prevent its destination being annulled, a part of the fluid, he says, must be absorbed by the surfaces, which it bathes: these surfaces must abstract nutritive juices from the blood, and they must return to the blood the refuse of their elaboration,—in other words, they must *aspire* and *expire*. Now, this double function cannot take place without the fluid being set in motion, and this motion must be the more constant and uniform as the double function is inherent in every molecule of the surface of the vessels. In this way he accounts for the mercury, placed in a tube communicating with an artery, being kept at the same height near to, or at a distance from, the heart, because, he says, it is not the action of the heart which supports it, but the action of the parietes of the vessels. Every surface, which aspires, provided it is flexible, must be, in its turn, he conceives, attracted by the substance aspired, and, consequently, by the act of aspiration alone, the motions of systole and diastole of the heart and arteries may be explained. When their inner parietes aspire—or assimilate the fluid—the heart will contract; when, on the contrary, they expire, owing to the mutual repulsion between the heart and the fluid, the former will dilate; and, as the movement of the heart is energetic on account of its size, its movements will add to the velocity of the circulation in the arteries, which will, therefore, besides their proper actions of aspiration and expiration, present movements isochronous with the pulsations of the heart. "Add to this accessory cause of arterial pulsations, the movements impressed by the aerial aspiration, which takes place in the lungs, and the circulation of the blood will no longer present insurmountable problems."

All this, we need scarcely say, is ingenious, but nothing more.

Such, then, are the chief accelerating causes of the circulation. There are some others, which at times accelerate, and at times retard; and others, again, that must always be regarded as impeding influences. All these are of a physical character, and apply equally to inert hydraulic machines, as to the pipes of the human body.

Friction always acts as a retarding force. That, which occurs between a solid and the surface on which it moves, can be subjected to calculation, but not so with a fluid; inasmuch as all its particles do not move equally: whilst one part is moving rapidly, another may be stationary, moving slowly, or even in a contrary direction, as is seen in rivers, where the middle of the stream always flows with much greater velocity than the sides. The same thing happens to water flowing through pipes; the water, which is in contact with the sides of the pipe, moves more slowly than that at the centre.

This retarding force is much diminished by the polished state of the inner surface of the blood-vessels, as is proved by the circumstance, that if we introduce an inert tube into an artery, the blood will not flow through it for any length of time.

Gravity may either be an active or retarding force, and is always

exerting itself, in both ways, on different sets of vessels. If, for example, the flow of blood to the lower extremity, by the arteries, be aided in the erect attitude by the force of gravity, its return by the veins is retarded by the same cause. Every observer must have noticed, that the pulse of an individual in health beats slower, when he is in the recumbent, than in the erect, attitude. This is owing to there being no necessity for the heart to make use of unusual exertions for the purpose of forcing the blood, against gravity, towards the upper part of the body. In therapeutics, the physician finds great advantage from bearing this influence in mind; and, hence, in diseases of the head,—as in inflammation of the brain, in apoplectic tendency, ophthalmia, &c.,—he directs the patient's head to be kept raised; whilst, in uterine affections, the horizontal posture, or one in which the lower part of the body is raised even higher than the head, is inculcated; and in ulcers or inflammatory diseases of the lower extremities, the leg is recommended to be kept elevated. Every one, who has had the misfortune to suffer from whitlow, must have experienced the essential difference, as regards degree of pain, produced by position. If the finger be held down, gravity aids the flow of blood by the arteries, and retards its return by the veins: the consequence is turgescence and painful distention; but if it be held higher than the centre of the circulation, the flow by the arteries is impeded, whilst its return by the veins is accelerated, and hence the marked relief afforded.

Curvatures.—Besides friction, the existence of curvatures has considerable effect on the velocity and quantity of the fluid passing through pipes. A jet will not rise as high from the pipe or adjutage of a reservoir, if there be an angular turn in it, as if the bend were a gradual curve or sweep. The expense of force, produced by such curvatures in arteries, is seen at each contraction of the ventricle,—the tendency in the artery to become straight, producing an evident movement, which has been called the *locomotion of the artery*, and has been looked upon, by some, as the principal cause of the pulse. This motion is, of course, more perceptible the nearer it is to the heart and the greater the vessel; hence it is more obvious at the arch of the aorta; and we can now understand why this arch should be so gradual.

We have a striking example of the force, used in this effort at straightening the artery, in the case of the popliteal artery, when the legs are crossed, and a curvature is thus produced. The force is sufficient to raise a weight of upwards of fifty pounds at each contraction of the ventricle, notwithstanding it acts at the extremity of so long a lever. This fact is sufficient to exhibit the inaccuracy of the notion of Bichat, that the curvatures in the arteries can have no effect in retarding the flow of blood. Such could only be the case, he thinks, if the vessels were empty at each systole.

The *anastomoses* of vessels have, doubtless, also some influence on the course of the blood; but it is impossible to appreciate it.

The superficial veins are especially liable to have the circulation mpeded by compression in the different postures of the body; but, by means of the numerous anastomoses that exist, if the blood cannot pass by one channel, it is diverted into others. Although, however, a forcible compression may arrest or retard the flow by these vessels, a slight degree of support prevents dilatation of the vein by the force of the blood passing into it, and thus favours its motion. The constant pressure of the skin is hence serviceable to the circulation through the subcutaneous veins; and if, by any means, the pressure is diminished, especially in those parts in which the blood has to make its way contrary to gravity—as in the lower extremities—varices or dilatations of the vessels arise, which are remedied by the mechanical compression of an appropriate bandage.

Attempts have been made to calculate the velocity with which the blood proceeds in its course; or, how long it would take for a globule of blood, setting out from the left side of the heart, to attain the right side. It is clear, that the data are, in the first place, totally insufficient for any approximation. We know not the total quantity of blood, contained in the vessels; the quantity sent into the artery at each contraction of the ventricle; the relative velocity of the arterial, venous, and capillary circulations; and if we knew them at any one moment, they are liable to incessant fluctuations, which would preclude any accurate average from being deduced. Were these circumstances insufficient to exhibit the inanity of such researches, the varying estimates of different observers would fully establish it. These assign the time occupied in the circulation from two minutes to fifteen or twenty hours! Moreover, the distance the globules would have to traverse might be very various. In the heart, the passage from one side to the other, by the coronary vessels is very short, whilst if it were to proceed to a remote part of the body, its course would be long and tedious.

Notwithstanding the absence of the requisite data, a recent writer has gone so far as to state the average velocity of the blood in the aorta, at about eight inches per second; whilst "the velocity in the extreme capillaries is found to be often less than one inch per minute." A similar estimate was made by Dr. Young; Hales too, estimated the velocity of the blood leaving the heart at 149.2 feet per minute, and the quantity of blood passing through the organ every hour at twenty times the weight of the blood in the body; but the judicious physiologist knows well, that in all operations, which are partly of a vital character, the results of every kind of calculation must be given with caution and humility. In the larger animals, as the whale, the quantity of the fluid circulating in the aorta must be prodigious. Dr. Hunter, in his account of the dissection of a whale, states that the aorta was a foot in diameter, and that ten or fifteen gallons of blood were probably thrown out of the heart at each stroke; so that this vessel is in the whale actually larger than the main pipe of the old water-

works at London Bridge; and the water, rushing through the pipe, has been conceived to have less impetus and velocity than that gushing from the heart of this leviathan.

The velocity of the circulating fluid, in the minute vessels, is necessarily less than in the larger. Their united calibres are much greater than that of the trunk with which they communicate. This diminution of velocity is in accordance with a law of hydrodynamics;—that when a liquid flows through a full pipe, the quantity which traverses the different sections of the pipe, in a given time, must be every where the same; so that where the pipe is wider the velocity diminishes; and, on the contrary, where it is narrower the velocity increases. That such is the case, in the living body, we know by the different velocity with which the blood flows, when a large or a small vessel is opened. Yet although the ordinary velocity of the blood in different arteries is different, it would seem, from the experiments of Poiseuille, that the pressure exerted on the blood in different parts of the body—as measured by the column of mercury, which the blood in different arteries will sustain—is almost exactly the same.

From what has been said, regarding the curvatures and angles of vessels, it will be understood, that the blood must proceed to different organs with different velocities. The renal artery is extremely short, straight, and large, and must consequently transmit the blood very differently to the kidney, from what the tortuous carotid does to the brain; or the spermatic artery, to the testicle. A different impulse must, consequently, be given to their corresponding organs by these different vessels. A great portion, however, of the impulse of the heart must fail to reach the kidney, short as the renal artery is, owing to its passing off from the aorta at a right angle; and, hence, the impulse of the blood on the kidney may not be as great as might be imagined at first sight.

The tortuosity of the carotid arteries is such as to greatly destroy the impetus of the blood; so that but trifling hemorrhage takes place when the brain is sliced away, on a living animal, although it is presumed, that one-eighth of the whole quantity of blood is sent to the encephalon. Rush supposed, that the use of the thyroid gland is to break the afflux of blood to the brain; for which its situation between the heart and the head appeared to him to adapt it; and he adduced, as farther arguments, the number of arteries which it receives, although effecting no secretion; as well as the effect on the brain, which he conceived to be caused by diseases, and by extirpation, of the thyroid; the latter having actually occasioned, in his opinion, in one case, inflammation of the brain, rapidly terminating fatally; whilst goitre is often accompanied by idiotism. The opinion, however, is so entirely conjectural, and the *facts*, on which it rests, so questionable, that it does not demand serious examination.

This leads us to remark, that the thyroid gland, as well as other

organs, with whose precise functions we are totally unacquainted,—as the thymus, spleen, and supra-renal capsules,—have been conceived to serve as diverticula or temporary reservoirs to the blood, when, owing to particular circumstances, that fluid cannot circulate properly in other parts. Lieutaud having observed, that the spleen is always larger when the stomach is empty than when full, considered, that the blood, when digestion is not going on reflows into the spleen, and that thus this organ becomes a diverticulum to the stomach.

The opinion has been indulged by many, with more or less modification. Dr. Rush's view was yet more comprehensive. He regarded the spleen as a diverticulum, not simply to the stomach, but to the whole system, when the circulation is violently excited, as in passion, or in violent muscular efforts, at which times there is danger of sanguineous congestion in different organs; and in support of his view, he invoked the spongy nature of the spleen; the frequency of its distention; the large quantity of blood distributed to it; its vicinity to the centre of the circulation; and the sensation referred to it in running, laughing, &c.

Broussais has still farther extended the notion of diverticula. He affirms, that they always exist in the vicinity of organs, whose functions are manifestly intermittent. In the fœtus, the blood does not circulate through the lungs as when respiration has been established: diverticula, he, therefore, considers to be necessary: these are the thymus and thyroid glands. The kidneys do not act in utero: hence the use of the supra-renal capsules as diverticula.

At birth, these organs are either wholly obliterated, if the organs to which they previously acted as diverticula have continuous functions; or they are only partly obliterated, if the functions are intermittent. Thus, the spleen continues as a diverticulum to the stomach, because its functions are intermittent through life; and the thymus disappears, when respiration is established: the liver and the portal system he regards as a reservoir, inservient to the reception of the blood, in cases of impediment to the circulation in different parts of the body.

These notions are entirely hypothetical. We shall see, hereafter, that our ignorance of the offices of the spleen, thymus, &c. is extreme; and we have already shown, that much more probable uses can be assigned to the portal system. The insufficiency of the doctrine of diverticula by Broussais is strikingly evidenced by the fact, that whilst the thymus gland disappears gradually in the progress of age, the thyroid remains, as well as the supra-renal capsules.

We have had occasion, more than once, to refer to the subject of the pulse, or to the beat, felt by the finger when applied over any of the larger arteries. The opinions of individuals have varied essentially regarding its cause. Whilst most physiologists have believed it to be owing to distention of the arteries, caused by each contrac-

tion of the left ventricle; some have admitted a systole and diastole of the vessel itself; others, as Bichat and Weitbrecht have thought that it is owing to the locomotion of the artery; others, that the impulse of the heart's contraction is transmitted through the fluid blood, as through a solid body; and others, as Dr. Young and Dr. Parry, that it is owing to the sudden rush forward of the blood in the artery without distention.

Bichat was one of the first, who was disposed to doubt, whether the dilatation of the artery, which was almost universally admitted, really existed; or if it did, whether it was sufficient to explain the phenomenon; and, since his time, numerous experiments have been made by Dr. Parry, the result of which satisfied him, that not the smallest dilatation can be detected in the larger arteries, when they are laid bare during life; nor does he believe, that there is such a degree of locomotion of the vessel, as can account for the effect produced upon the finger. He ascribes the pulse, therefore, to "impulse of distention from the systole of the left ventricle, given by the blood, as it passes through any part of an artery contracted within its natural diameter." Dr. Bostock appears to coincide with Dr. Parry if we understand him rightly, or at all. "According to this (Dr. Parry's) doctrine," he remarks, "we must regard the artery as an elastic and distensible tube, which is at all times filled, although with the contained fluid not in an equally condensed state, and that the effect produced upon the finger depends upon the amount of this condensation, or upon the pressure which it exercises upon the vessel, as determined by the degree, in which it is capable of being compressed."

Most of the theories of the pulse take the contractility of the artery too little into account. In pathology, where we have an opportunity of observing the pulse in various phases, we meet with sensations, communicated to the fingers, which it is difficult to explain upon any theory, except that of the compound action of the heart and arteries. The impulse is obviously that of the heart, and although the fact of distention escaped the observation of Bichat, Parry, Weibrecht, Lamure, Döllinger, Rudolphi, Jäger, and others, we ought not to conclude, that it does not occur. It is, indeed, difficult for us to believe, that such an impulse can be communicated to a fluid filling an elastic vessel without pulsatory distention supervening. In opposition, too, to the negative observations of Bichat and Parry, we have the positive averment of Dr. Hastings, and of Poiseuille, Österreicher, Ségalas, and Wedemeyer, that the alternate contraction and dilatation of the larger arteries, was clearly seen.

The pulsations of the different arteries are pretty nearly synchronous with that of the left ventricle. Those of the vessels near the heart may be regarded as almost wholly so, but an appreciable interval exists in the pulsations of the more remote vessels.

We have remarked, that the arterial system is manifestly more

or less affected by the nerves distributed to it; that it may be stimulated by irritants, applied to the great nervous centres, or to the nerves passing to it; and this is, doubtless, the cause of many of the modifications of arterial tension, that we notice in disease. No inflammation can affect any part of the system, for any length of time, without both heart and arteries participating, and affording us unequivocal signs of such inflammation. This, however, is a subject that belongs more especially to pathology.

The ordinary number of pulsations, per minute, in the healthy adult male, is from seventy to seventy-five; but this varies greatly according to temperament, habit of life, &c. In some individuals in perfect health, the number of beats is singularly few. The pulse of a person, known to the author, was on the average thirty-six per minute; and Lizzari affirms, that he knew a person in whom it was not more than ten. It is not improbable, however, that, in these cases, obscure beats may have taken place intermediately, and yet not have been detected. In a case of carditis, in which the author felt great interest, the pulse exhibited a decided intermission, every few beats, yet the heart beat its due number of times; the intermission of the pulse at the wrist consisting in the loss of one of the beats of the heart. It was not improbable but that, in this case, the contractility of the aorta was unusually developed by the inflammatory condition of the heart; and that the flow of blood from the ventricle was thus diminished or entirely impeded.

The pulse of the female is usually eight or ten beats in a minute quicker than that of the male. In infancy, it is generally irregular, intermitting, and always rapid, and it gradually becomes slower until old age. It is, of course; impossible to arrive at any accurate estimate of the comparative frequency at different periods of life, but the average of the following numbers, on the authority of Heberden and Sömmering, may be regarded as approximations.

Ages.	Number of beats per minute, according to	
	HEBERDEN.	SÖMMERING.
At birth, ...	130 to 140	Do.
One month, ...	120	—
One year, ...	120 to 108	120
Two years, ...	108 to 90	110
Three years, ...	90 to 80	90
Seven years, ...	72	—
Twelve years, . . .	70	—
Puberty, ...	—	80
Adult, ...	—	70
Old age, ...	—	60

The pulse—strange to say—may be wholly absent, without the

health seeming to be interfered with. A case of this kind is referred to by Dr. Samuel Jackson, as having occurred in the mother of a physician of Philadelphia. The pulse disappeared during an attack of acute rheumatism, and could never again be observed during her life. Yet she was active in body and mind, and possessed unusual health. In no part of the body could a pulse be detected. Dr. Jackson attended her during a part of her last illness—inflammation of the intestines—no pulse existed. She died whilst he was absent from the city, and no examination was made to elucidate the cause of this remarkable phenomenon.

Lastly, the chief uses of the circulation are,—to transmit to the lungs the products of absorption, in order that they may be converted into arterial blood; and to convey to the different organs this arterial blood, which is not only necessary for their vitality, but is the fluid on which the different processes of nutrition, calorification and secretion are effected. These functions will engage us next. We may remark, in conclusion, that the agency of the blood, as the cause of health or insalubrity, has had greater importance assigned to it than it merits; and that although it may be the medium, by which the source of disease is conveyed to other organs, we cannot look to it as the seat of those taints that are commonly referred to it. "Upon the whole," says Dr. Good, "we cannot but regard the blood as, in many respects, the most important fluid of the animal machine; from it all the solids are derived and nourished, and all the other fluids are secreted; and it is hence the basis or common pabulum of every part. And as it is the source of general health, so it is also of general disease. In inflammation, it takes a considerable share, and evinces a peculiar appearance. The miasms of fevers and exanthems are harmless to every part of the system, and only become mischievous when they reach the blood; and emetic tartar, when introduced into the jugular vein, will vomit in one or two minutes, although it might require, perhaps, half an hour if thrown into the stomach, and in fact does not vomit till it has reached the circulation. And the same is true of opium, jalap, and most of the poisons, animal, mineral and vegetable. If imperfectly elaborated, or with a disproportion of some of its constituent principles to the rest, the whole system partakes of the evil, and a dysthesis or morbid habit is the certain consequence; whence tabes, atrophy, scurvy, and various species of gangrene. And if it become once impregnated with a peculiar taint, it is wonderful to remark the tenacity with which it retains it, though often in a state of dormancy and inactivity for years or even entire generations. For as every germ and fibre of every other part is formed and regenerated from the blood, there is no other part of the system, that we can so well look to as the seat of such taints, or the predisposing cause of the disorders I am now alluding to; often corporeal, as gout, struma, phthisis; sometimes mental, as madness; and occasionally both, as cretinism."

This picture is largely overdrawn. Setting aside the pathological allusions, which are erroneous in assigning to the blood what properly belongs to the capillaries, how can we suppose a taint to continue for years, or even entire generations, in a fluid which is perpetually undergoing renovation, and, at any distant interval cannot be presumed to have one of its quondam particles remaining?

If all hereditary diseases were derived from the mother, we could better comprehend this doctrine of taints; inasmuch as, during the whole of fœtal existence, she transmits the pabulum for the support of her offspring: the child is, however, equally liable to receive the taint from the father, who supplies no pabulum, but merely a secretion from the blood at a fecundating copulation, and from that moment cannot exert any influence upon the character of his progeny. The impulse, then, to this or that organization, or conformation, must be given from the moment of union of the particles, furnished by each parent at a fecundating intercourse; and it is probable, that no subsequent influence is exerted even by the mother. She affords the pabulum, but the embryo accomplishes its own construction, as independently of the parents as the chick *in ovo*.

The operation of *transfusion*,—as well as the *infusion* of medicinal agents,—was adduced by us to prove the course of the circulation to be by the arteries into the veins. Both these operations were suggested by the discovery of Harvey. The former, more especially, was looked upon as a means of curing all diseases, and of renovating the aged, *ad libitum*. The cause of every disease and decay was presumed to reside in the blood; and, consequently, all that was conceived to be necessary was to remove the faulty fluid, and to substitute pure blood obtained from a healthy animal, in its place.

As a therapeutical agent, the history of this operation does not belong to physiology. The detail of the fluctuation of opinions regarding it, and its total disuse, are given at some length in the Histories of Medicine, to which we must refer the reader.

Recently, it has been revived by Dr. Blundell, of London, and by MM. Prévost and Dumas; the first of whom has employed it with safety, and he thinks, with happy effects, in extensive uterine hemorrhage. All these gentlemen remark, that it can only be adopted, with perfect safety, in animals of like kinds; or in those, the globules of whose blood are of similar configuration.

The introduction of the practice of infusing medicinal agents into the blood was coeval with that of transfusion. Both, indeed, are affirmed to have been commenced in 1657, at the suggestion of Sir Christopher Wren. It is a singular fact, that, in cases of infusion, medicinal substances are found to exert their specific actions upon certain parts of the body, precisely in the same manner as if they had been received into the stomach. Tartar emetic, for example, vomits, and castor oil purges, not only as certainly, but with much

greater speed; for whilst the former, as before remarked, requires to be in the stomach for fifteen or twenty minutes, before vomiting is excited, it produces its effect in one or two minutes, when thrown into the veins. Dr. E. Hale, Junr. of Boston, has published an interesting pamphlet on this subject, comprising the Boylston Medical Prize Dissertations, for the years 1819 and 1821. In this he traces the history of the operation, and details several interesting experiments upon animals; and one upon himself, which consisted in the introduction of a quantity of castor oil into the veins.

In this experiment, he did not experience much inconvenience immediately after the injection; but very speedily he felt an oily taste in the mouth, which continued for a length of time, and the medicine acted powerfully as a cathartic.

Considerable difficulty was experienced in the introduction of the oil, to which circumstance Magendie ascribes Dr. Hale's safety; for it is found, by experiments on animals, that viscid fluids, such as oil, are unable to pass through the pulmonary capillaries; in consequence of which the circulation is arrested, and death follows. Such also appears to have been the result of the experiments of Dr. Hale with powdered substances.

The injection of medicines into the veins has been largely practised at the Veterinary School of Copenhagen, and with complete success,—the action of the medicine being incomparably more speedy, and the dose required much less. It is rarely employed by the physician, except in his experiments on animals; but it is obvious, that it might be had recourse to, with happy effects, where narcotic and other poisons have been taken, and where the mechanical means for their removal are not at hand.

It was the opinion of Bichat, that if a bubble of air accidentally enters the veins, it causes sudden death; but the experiments of Nysten and Magendie have shown, that if it be introduced slowly, no unfortunate event need be apprehended. When forced in rapidly, the respiration speedily becomes remarkably accelerated; a peculiar noise is heard in the chest, produced by the agitation of the air in the venæ cavæ, right auricle and ventricle, and pulmonary artery; and the animal soon expires. Dissection exhibits the heart, and especially its right side, with the pulmonary artery, forcibly distended with air, or with a slightly sanguineous foam, which is almost wholly composed of air. Air is also found in the cellular tissue of the lung, producing emphysema of the organ, and in the arteries of the whole of the body, especially in those of the brain.

The mortal effects from the sudden introduction of air into the veins, in extensive injuries of the neck, have been already referred to. At the moment of inspiration the air is drawn into the vein; the noise is heard in the heart, as in the experiment just detailed, and the animal quickly dies.

Magendie remarks, that some animals will admit enormous quantities of air into the veins without perishing, and he instances the

case of a horse, into whose veins he pushed, as rapidly and forcibly as he was able, forty or fifty pints of air without occasioning immediate death, although the animal ultimately expired.

In concluding this subject, a brief allusion to the circulatory apparatus of other parts of the animal kingdom may be interesting and instructive.

In the *mammalia* in general, the inner structure of the heart is the same as in man, but its situation differs materially; and, in some of them, as in the stag and pig, two small flat bones, called *bones of the heart*, exist, where the aorta arises from the left ventricle. In the amphibious mammalia and the cetacea, it has been supposed that the foramen ovale, situated in the septum between the auricles, is open as in the human fœtus, to allow those animals to pass a considerable time under water without breathing; but the observations of Blumenbach, Cuvier, and others seem to show, that it is almost always closed. Sir Everard Home found it open in the sea otter, in two instances; but these are regarded by naturalists as exceptions to the general rule.

In several of the web-footed mammalia and cetacea, as in the common otter, the sea otter, and the dolphin, particular vessels are found to be always greatly enlarged and tortuous;—a structure which has been chiefly noticed in the vena cava inferior, and which is supposed to serve the purpose of a diverticulum, whilst the animal is under water, or to receive a part of the returning blood, and to retain it until respiration can be resumed.

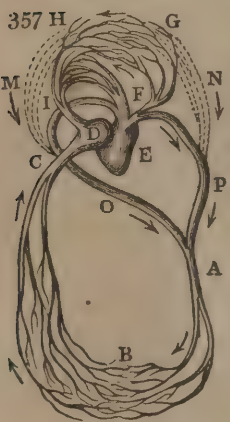
In *birds*, the structure of the heart universally possesses a singular peculiarity. Instead of the right ventricle having a membranous valve, as in the left, and as in all the mammalia, it is provided with a strong, tense, and nearly triangular muscle, which aids in the propulsion of the blood from the right side of the heart into the lungs. This is presumed to be necessary, in consequence of their lungs not admitting of expansion like those of the mammalia, and of their being connected with numerous air-cells.

The heart of the *reptiles* or *amphibia* in general consists either of only one ventricle, or of two ventricles; which freely communicate, so as essentially to constitute but one. The number of auricles always corresponds with that of the ventricles. That the cavities—auricular or ventricular—are, however, single, although apparently double, is confirmed by the fact, that, in all, there is only a single artery proceeding from the heart, which serves both for the pulmonic and systemic circulations. After this vessel has left the heart, it divides into two branches, by one of which a part only of the blood is conveyed to the lungs, whilst the other proceeds to the different parts of the body. These two portions are united in the heart, and after being mixed together, are sent again through the great artery.

In these animals, therefore, aeration is obviously less necessary

than in the higher classes; and we can thus understand many of their peculiarities; how the circulation may continue, when the animal is so situated as to be incapable, for a time, of respiration; and the great resistance to ordinary deranging influences, by which they are characterized.

Fig. 132.

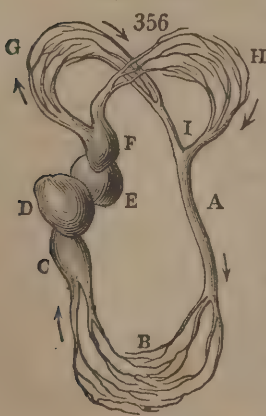


The marginal figure represents the circulatory apparatus of the *frog*; in which E is the ventricle and D the auricle. From the former arises the aorta F, which soon divides into two trunks. These, after sending branches to the head and neck, turn downwards, (O and P), and unite in the single trunk A. This vessel sends off arteries to the body and limbs, which ultimately terminate in veins, and unite to form the vena cava C.

From each of the trunks into which the aorta bifurcates at its origin, arise the arteries F. These are distributed to the lungs, and communicate with the pulmonary veins, which return the blood to the auricle, D, where it becomes mixed with the blood of the systemic circulation.

In the tadpole state, the circulation is branchial, as in fishes. The heart then sends the whole of its blood to the *branchiæ* or gills, and it is returned by veins following the course of the dotted lines M and N, which unite to form the descending aorta. As the lungs undergo their developement, small arterial branches arise from the aorta and are distributed to those organs, and in proportion as these arteries enlarge, the original branchial arteries diminish; until ultimately they are obliterated, and the blood flows wholly through the enlarged lateral trunks, O and P, which, by their union, form the descending aorta.

Fig. 133.



In *fishes*, the heart is extremely small, in proportion to the body; and its structure is simple; consisting of a single auricle and ventricle, D and E, (Fig. 133). From the ventricle E an arterial trunk arises, which, in most fishes, is expanded, into a kind of bulb, F, as it leaves the heart, and proceeds straight forward to the *branchiæ* or *gills*, G and H. From these, the blood passes into a large artery, A, analogous to the aorta, which proceeds along the spine, and conveys the blood to the various parts of the system; and, by vena cava, C, the blood is returned to the auricle. This is, consequently, a case of single circulation.

Insects appear to be devoid of blood-vessels. Cuvier examined all the organs in them, which, in red-blooded animals, are most vascular, without discovering the least appearance of a blood-vessel, although extremely minute ramifications of the tracheæ were obvious in every part. Insects, however, both in their perfect and larva state, have a membranous tube, running along the back, in which alternate dilatations and contractions are perceptible; and which has been considered as their heart; but it is closed at both ends, and no vessels can be perceived to originate from it. To this the innumerable ramifications of the tracheæ convey the air, and thus, as Cuvier has remarked, "le sang ne pouvant aller chercher l'air, c'est l'air, qui va chercher le sang;" ("the blood not being able to go in search of air—the air seeks the blood.")

Fig. 134.

Interior of the leech.

a a. Respiratory cells.—*b b*. Two large arteries.—*c c*. Mucous glands.—*d d*. Glands connected with the testicles.—*e e*. Testicles.—*f*. Penis.—*g*. Uterus.

Lastly, in many genera of the class *vermes*, particularly amongst the molluscous and testaceous animals, there is a manifest heart, which is sometimes of a singular structure. Some of the bivalves are affirmed to have as many as four auricles; whilst many animals, as the leech and *Lumbricus marinus*, have no heart; but circulating vessels exist, in which contraction and dilatation are perceptible.

The marginal figure of the interior of a leech, as given by Sir Everard Home, will exhibit the mode of circulation and respiration in that animal. There is no heart, but a large vessel on each side of the animal. The water is received, through openings in the belly, into the cells or respiratory organs, and passes out through the same.

NUTRITION.

The investigation of the phenomena of the circulation has exhibited the mode in which arterial blood is distributed over the body in minute vessels, not appreciable by the naked eye, and often not even with the microscope, and so numerous, that it is impossible for the finest-pointed instrument to be forced through the skin without penetrating one, and perhaps several. We have seen, likewise, that, in the capillary system of vessels, this arterial blood is changed into venous; and it was observed, that, in the same system, parts are deposited or separated from the blood, and certain phenomena accomplished into the nature of which we have now to inquire, beginning with those of *nutrition*, which comprise the incessant changes that are taking place in the body, both of absorption and deposition, and which effect the decomposition and renovation of each organ. Nutrition is well-defined by Adelon as the action, by which every part of the body, on the one hand, appropriates or assimilates to itself a portion of the blood distributed to it; and, on the other, yields to the absorbing vessels a portion of the materials that previously composed it.

The precise character of the apparatus, by which this important function is accomplished we have no means of knowing. All admit, however, that the old matter must be taken up by absorbents, and the new be deposited by arteries, or by vessels, continuous with them. As the precise arrangement of these minute vessels is not perceptible by the eye, even when aided by powerful instruments, their arrangement has given rise to much controversy. Whilst some have imagined lateral pores in the capillary system of vessels, for the transudation of nutritive deposits; others have presumed, that inconceivably small vessels are given off from the capillary system, which constitute a distinct order, and whose function it is to exhale the nutritive substance. Hence, they have been termed *exhalants* or *nutritive exhalants;* but the physiological student must bear in mind, that whenever the term is used by writers, they do not always pledge themselves to the existence of any distinct set of vessels, but merely mean the capillary vessel, whatever may be its nature, which is the agent of nutrition, and conveys the blood to the tissues—where bone is needed—muscle, tendon, ligament, &c. as the case may be.

In investigating the physiology of nutrition, two topics necessarily divide our attention; 1st, The action of *decomposition*, by which the organ yields to the absorbing vessels a portion of its constituents; and 2dly, The action of *composition*, by which the organ assimilates

a part of the arterial blood that enters it, and supplies the loss, which it has sustained by the previous action of decomposition.

The former of these actions obviously belongs to the function of absorption; but its physiology, it will be recollected, was deferred, in consequence of its close application to the function we are now considering. It comprises what is meant by *interstitial, organic,* or *decomposing absorption,* and does not require many comments, after the long investigation of the general phenomena of absorption into which we entered. The conclusion, at which we then arrived, was,—that the chyliferous and lymphatic vessels form only chyle and lymph respectively, refusing the admission of all other substances; that the veins admit every liquid which possesses the necessary tenuity; and that, whilst all the absorptions,—which require the substance acted upon to be decomposed and transformed,—are effected by the chyliferous and lymphatic vessels, those that demand no alteration are accomplished through the coats of the veins by imbibition.

It is easy, then, to deduce the agents to which we refer the absorption of decomposition. As it is exerted on solids, and as these cannot pass through the coats of the vessels in their solid condition, it follows, that other agents than the veins must accomplish the process; and, again, as we never find in the lymphatic vessels anything but lymph, and as we have every reason to believe that an action of selection is exerted at their extremities, similar to that of the chyliferous vessels on the heterogeneous substances exposed to them, we naturally look to the lymphatics as the main, if not the sole, organs concerned in the absorption of solids.

It has been maintained, by some physiologists, that the different tissues are endowed with a vital attractive and elective force, which they exert upon the blood;—that each tissue attracts only those constituents of which it is itself composed; and thus, that the whole function of nutrition is an affair of elective affinity; but this, obviously, cannot be the force, that presides over the original formation of the tissues, in the embryo. An attraction cannot be exerted by parts, not yet in existence. To account for this, it has been imagined, that a peculiar force is destined to preside over formation and nutrition, and to this force various names have been assigned. By most of the ancients, it was termed *facultas formatrix, nutrix, auctrix;* by Van Helmont, *Blas alterativum;* and by Bacon, *motus assimilationis.* It was the *facultas vegetativa* of Harvey; the *anima vegetativa* of Stahl; the *puissanee du moule intérieur* of Buffon; the *vis essentialis* of C. F. Wolff; the Bildungstrieb or *nisus formativus* of Blumenbach and most of the German writers. This force is meant, when writers speak of the *plastic force, force of nutrition, force of formation, force of vegetation.* Whatever difference there may be in the terms selected, all appear to regard it as charged with maintaining, for a certain length of time, living bodies, and all their parts, in the possession of their due

composition, organization, and vital properties, and of putting them in a condition, during a certain period of their existence, to produce beings of the same kind as themselves. It is obvious, however, that none of these terms elucidate the intricate phenomena of nutrition, and that none express more than—that living bodies possess a *vital force*, under the action of which formation and nutrition are accomplished.

When, again, we speak of the tissues being endowed with an elective as well as attractive force, which they exert upon the blood, we allude only to the mysterious controlling power—vitality—the nature of which is so inscrutable. A recent intelligent writer—Dr. Southwood Smith—has thus embodied the ideas of those who invoke this action. "In every part of the body, in the brain, the heart, the lung, the muscle, the membrane, the bone, each tissue attracts only those constituents of which it is itself composed. Thus the common current, rich in all the proximate constituents of the tissues, flows out to each. As the current approaches the tissue, the particles appropriate to the tissue feel its attractive force, obey it, quit the stream, mingle with the substance of the tissue, become identified with it, and are changed into its own true and proper nature. Meantime, the particles which are not appropriate to that particular tissue, not being attracted by it, do not quit the current, but, passing on, are borne by other capillaries to other tissues, to which they are appropriate, and by which they are apprehended and assimilated. When it has given to the tissues the constituents with which it abounded, and received from them particles no longer useful, and which would become noxious, the blood flows into the veins, to be returned by the pulmonic heart to the lung, where, parting with the useless and noxious matter it has accumulated, and, replenished with new proximate principles, it returns to the systemic heart, by which it is again sent back to the tissues." Particles of blood are seen to quit the current, and mingle with the tissues; particles are seen to quit the tissues, and mingle with the current; but all that we can see, as Dr. Smith has remarked, with the best aid we can get, does but bring us to the confines of the grand operations that go on, of which we are altogether ignorant.

We have said, that the main, if not the sole agents of the absorption of solids, are the lymphatics. Almost all admit, that they receive the product of absorption; but all do not admit, that the action of taking up solid parts is accomplished immediately by the absorbents. They who think, that a kind of spongy tissue or "parenchyma" is situated at the radicles of the absorbent vessels, believe, that this sponge possesses a vital action of absorption, when bodies, possessing the requisite constitution and consistence, are put in contact with it; but they maintain, that the solid parts of the body are broken down by the same agents—the extreme arteries—which secreted them, and that, when reduced to the proper fluid condition, they are imbibed by the parenchyma, and conveyed into

the lymphatics. If the existence of this sponge were demonstrated, the above explanation would be the only one, perhaps, that could be admitted; for the sponge could scarcely be conceived to do more than imbibe; it could not break down the solid textures, and reduce them to lymph—the only fluid, which, as we have seen, is ever met with in the lymphatic vessels. But its existence is altogether suppostitious. Besides, the arrangement has not been invoked in favour of the chyliferous vessels, which are so analogous in their organization and functions to the lymphatics. It has not been contended, that the arteries of the intestinal canal form the chyle from the alimentary matters in the small intestine, and that the office of the chyliferous vessels is restricted to the reception of this chyle, imbibed and brought in contact with their radicles by this ideal sponge or parenchyma.

We have before shown, that there is every reason for the belief, that a vital action of selection and elaboration exists at the very radicles of the chyliferous vessels: and the same may be inferred of the radicles of the lymphatics. The great difficulty is in believing how either exhaling artery, or absorbing lymphatic can reduce the solid matter—of bone, for example—to the necessary constitution and consistence to enter the lymphatics; but we can conceive, that the latter as readily as the former, by virtue of its vital properties—for the operation must be admitted by all to be *vital*—and by means of its contained fluid, may soften the solid so as to admit of its being received into the vessel.

We leave, then, wholly unexplained, the mysterious operation by which these absorbents are enabled to reduce to their elements, bone, muscle, tendon, &c., and to recompose them into the form of lymph. Dr. Bostock fancifully suggests, that the first step in this series of operations is the death of the part, by which expression he means, that it is no longer under the influence of arterial action. "It therefore ceases to receive the supply of matter which is essential to the support of all vital parts, and the process of decomposition necessarily commences." The whole of his remarks on this subject are eminently gratuitous, and appear to be suggested by his extreme unwillingness to ascribe the process to anything but physical causes. If there is, however, any one phenomenon of the animal economy, which is more manifestly referable to vital action than another, it is the function of nutrition, both as regards the absorption of parts already deposited, and the exhalation of new; and it is wise to confess our utter ignorance of the mode in which it is accomplished. We know that the blood contains most of the principles that are necessary for the nutrition of organs, and that it must contain the elements of all. Fibrine, albumen, fat, osmazome, salts, &c. exist in it, and these are deposited, as the blood traverses the tissues; but why one should be selected by one set of vessels, as by the exhalants of bone, and another by another set, and in what manner the elements of those, not ready formed in the

blood, are brought together, is totally unknown to us. Blood has been designated as "liquid flesh,"—*chair coulante*,—but something more than simple transudation through vessels is necessary to form it into flesh, and to give it the compound organization of fibrine, gelatine, osmazome, &c.—in the form of muscular fibre and cellular membrane—which we observe in the muscle.

Nothing, perhaps, more clearly exhibits our want of knowledge on the subject than the following vague attempt at solving the mystery by one of the most distinguished physiologists of the age. —"Some immediate principles, that enter into the composition of the organs or of the fluids, are not found in the blood,—such as gelatine, uric acid, &c. They are consequently formed at the expense of other principles, in the parenchyma of the organs, and by a chymical action, the nature of which is unknown to us, but which is not the less real, and must necessarily have the effect of developing heat and electricity."

It is the action of nutrition, that occasions the constant fluctuations in the weight and size of the body, from the earliest embryo condition till advanced life. The cause of the developement or *growth* of organs and of the body generally, as well as of the limit, accurately assigned to such developement, according to the animal or vegetable species, is dependent upon vital laws that are unfathomable. Nor are we able to detect the precise mode in which the growth of parts is effected. It cannot be simple extension, for the obvious reason that the body and its various compartments augment in weight as well as in dimension. In the large trees of our forests, we find a fresh layer or ring added each year to the stem, until the full period of developement; and it has been supposed that the growth of the animal body may be effected in a similar manner, both as regards its soft and harder materials, that is, by layers deposited externally. That the long bones lengthen at their extremities is proved by an experiment of Mr. Hunter. Having exposed the tibia of a pig, he bored a hole into each extremity of the shaft, and inserted a shot. The distance between the shots was then accurately taken. Some months afterwards, the same bone was examined, and the shots were found at precisely their original distance from each other; but the extremities of the bone had extended much beyond their first distance from them.

The flat bones also increase by a deposition at their margins, and the long bones by a similar deposition at their periphery,—circumstances strongly exhibiting the analogy between the successive developement of animals and vegetables.

Exercise or rest, freedom from or presence of pressure produce augmentation of the size of organs or the contrary; and there are certain medicines, as iodine, which occasion the emaciation of particular organs only—as of the female mammæ. The effects of disease is likewise, in this respect, familiar and striking.

The ancients had noticed the changes effected upon the body by

the function we are considering, and attempted to estimate the period at which a thorough conversion might be accomplished, so that not one of its quondam constituents should be present. By some, this was supposed to be seven years; but Bernouilli reduced it to three. It is hardly necessary to say, that in such a calculation we have nothing but conjecture to guide us. The nutrition of the body and of its parts varies, indeed, according to numerous circumstances. It is not the same during the period of growth as subsequently, when the absorption and deposition are balanced, so far at least as concerns the augmentation of the body in one direction. Particular organs have, likewise, their period of developement, at which time the nutrition of such parts must necessarily be more active,—the organs of generation, for example, at the period of puberty; the enlargement of the mammæ in the female; the appearance of the beard and the amplification of the larynx in the male, &c.,—all these changes occur after a determinate plan.

The activity of nutrition appears to be increased by exercise, at least in the muscular organs; hence the well-marked muscles of the arm in the prize-fighter, of the legs in the dancer, &c. The muscles of the male are, in general, much more clearly defined; but the difference between those of the hard-working female and of the inactive male may not be very apparent.

There are several textures of the body that do not experience nutrition, but, when once deposited, appear to remain permanently, such as the epidermis, the nails, the teeth, the colouring matter of the skin, and, it is presumed, the cartilages,—especially the inter-articular. The most active in their nutrition are the glands, muscles, and skin, which alter their character—as to size, colour and consistence—with great rapidity; whilst the tendons, fibrous membranes, bones, &c. are much less so, and are altered more slowly by the effect of disease.

A practice, which prevails amongst certain professions and people, would seem at first sight to show that the nutrition of the skin cannot be energetic. Sailors are frequently in the habit of forcing gunpowder through the cuticle with a pointed instrument, and of figuring the initials of their names upon the arm in this manner: the particles of the gunpowder are thus driven into the cutis vera and remain for life. The operation of *tattooing*, or of puncturing and staining the skin, prevails in many parts of the globe and especially in Polynesia, where it is looked upon as greatly ornamental. The art is said to be carried to its greatest perfection in the Washington or New Marquesas Islands; where the wealthy are often covered with various designs from head to foot; subjecting themselves to a most painful operation for this strange kind of personal decoration. The operation consists in puncturing the skin with some rude instrument, according to figures previously traced upon it, and then rubbing into the punctures a thick dye, frequently composed of the ashes of the plant that furnishes the colouring matter. The marks,

Fig. 135.

Tattoed head of a New Zealand Chief.

thus made, are indelible. Magendie asks:—"How can we reconcile this phenomenon with the renovation, which, according to authors," (and he might have added, according to himself,) "happens to the skin?" It does not seem to us to be in any manner connected with the nutrition of the skin. The colouring matter is an extraneous substance, which takes no part in the changes constantly going on in the tissue in which it is imbedded; and the circumstance seems to afford a negative argument in favour of venous absorption. Had the substance possessed the necessary tenuity it would have entered the veins like other colouring matters; but the particles are too gross for this, and hence they remain free from all absorbent influence.

CALORIFICATION, OR ANIMAL TEMPERATURE.

The function, which we have now to consider, is one of the most important to organic existence, and one of the most curious in its causes and results. It has, consequently, been an object of interesting examination with the physiologist, both in animals and plants, and as it has been presumed, by a large class of speculatists, to be greatly owing to respiration, it has been a favourite topic with the chymist also. Most of the hypotheses, devised for its explanation, have, indeed, been of a chymical character; and hence it will be advisable to premise a few observations regarding the physical relations of *caloric* or the *matter of heat*,—an imponderable body, according to common belief, which is generally distributed throughout nature. It is this that constitutes the *temperature of bodies*,—by which is meant, the sensation of heat or cold, which we experience, when bodies are touched by us; or the height at which the mercury is raised or depressed by them, in the instrument called the *thermometer*;—the elevation of the mercury being caused by the caloric entering between its particles, and thus adding to its bulk; and the depression being produced by the abstraction of caloric.

Caloric exists in bodies in two states;—in the *free*, *uncombined* or *sensible*, and in the *latent* or *combined*. In the latter case, it is intimately united with the other elementary constituents of bodies, and is neither indicated by the feelings nor by the thermometer. It has, consequently, no agency in the temperature of bodies; but, by its proportion to the force of cohesion, it determines their condition;—whether they shall be solid, liquid or gaseous. In the former case, caloric is simply interposed between the molecules, and is incessantly disengaged, or abstracted from surrounding bodies; and, by impressing the surface of the body or by acting upon the thermometer, it indicates to us their temperature.

Equal weights of the same body, at the same temperature, contain the same quantities of caloric; but equal weights of different bodies, at the same temperature, have by no means the same quantities. The quantity, which one body contains, compared with that in another is called its *specific caloric*, or *specific heat;* and the power or property, which enables bodies to retain different quantities of caloric, is called *capacity for caloric*. If a pound of water, heated to 156°, be mixed with a pound of quicksilver at 40°, the resulting temperature is 152°,—instead of 98°, the exact mean. The water, consequently, must have lost four degrees of temperature, and the quicksilver gained 112°; from which we deduce, that the quantity

of caloric, capable of raising one pound of mercury from 40° to 152° is the same as that required to raise one pound of water from 152° to 156°; or, in other words, that the same quantity of heat, which raises the temperature of a pound of water four degrees, raises the same weight of mercury one hundred and twelve degrees. Accordingly, it is said, that the *capacity* of water for heat is to that of mercury, as 28 to 1; and that the *specific heat* is twenty-eight times greater.

All bodies are capable of giving and taking free caloric, and, consequently, all have a temperature. If the quantity given off be great, the temperature of the body is elevated. If it take heat from the thermometer, it is cooler than the instrument.

In inorganic bodies, the disengagement of caloric is induced by various causes; such as electricity, friction, percussion, compression, the change of condition from a fluid to a solid state; and by chymical changes, giving rise to new compounds, so that the caloric, which was previously latent, becomes free. If, for example, two substances, each containing a certain amount of specific heat, unite, so as to form a compound, whose specific heat is less, a portion of caloric must be set free, and this will be indicated by a rise in the temperature. It is this principle, which is chiefly concerned in some of the theories of calorification.

The subject of the equilibrium and conduction of caloric has already been treated of, under the sense of touch; where several other topics were discussed, that bear more or less upon the present inquiry. It was there stated, that inorganic bodies speedily attain the same temperature, either by radiation or conduction; so that the different objects in an apartment will exhibit the same degree of heat by the thermometer, but the temperature of animals, being a vital operation, they retain the degree of heat peculiar to them, with but little modification from external temperature. There is a difference, however, in this respect, sufficient to cause the partition of animals into two great divisions—the *warm-blooded* and the *cold-blooded;* the former comprising those whose temperature is high, and but little influenced by that of external objects;—the latter those whose temperature is greatly modified by external influences. The range of the temperature of the warm-blooded—amongst which are all the higher animals—is limited; but of the cold-blooded extensive.

The following Table exhibits the peculiar temperature of various animals in round numbers;—that of man being 98° or 100°, when taken under the tongue. The temperature in the axilla is something less. In the latter situation, Dr. Edwards found it to vary, in twenty adults, from 96° to 99° Fahr., the mean being 97°.5.

Animals.	Observers.	Temperature.
Arctic fox, - - - - - -	Capt. Lyon.	107
Arctic wolf, - - - - - -	Do.	105
Squirrel, - - - - - - -	Pallas.	
Hare, - - - - - - -	Do.	104
Whale, - - - - - - -	Scoresby.	
Arctomys citillus, zizil,—in summer, - -	Pallas.	103
Do. when torpid, - - -	Pallas.	80 to 84
Goat, - - - - - - -	Prévost & Dumas.	103
Bat, in summer, - - - - -	Do.	102
Musk, - - - - - - -	Do.	
Marmota bobac—Bobac, - - - -	Do.	101 or 102
House mouse, - - - - - -	Do.	101
Arctomys marmota, marmot,—in summer, -	Do.	101 or 102
Do. when torpid, - - - -	Do.	43
Rabbit, - - - - - - -	De la Roche.	100 to 104
Polar bear, - - - - - -	Capt. Lyon.	100
Dog, - - - - - - -	Martine.	100 to 103
Cat, - - - - - - -	Do.	
Swine, - - - - - - -	Do.	
Sheep, - - - - - - -	Do.	
Ox, - - - - - - -	Do.	
Guinea-pig, - - - - - -	De la Roche	100 to 102
Arctomys glis, - - - - - -	Pallas.	99
Shrew, - - - - - - -	Do.	98
Young wolf, - - - - - -	Do.	96
Fringilla arctica, Arctic finch, - - -	Braun.	111
Rubecola, redbreast, - - - - -	Pallas.	
Fringilla linaria, lesser red poll, - -	Do.	110 or 111
Falco palumbarius, goshawk, - - -	Do.	110
Caprimulgus Europæus, European goat-sucker,	Do.	
Emberiza nivalis, snow bunting, - -	Do.	109 or 110
Falco lanarius, lanner, - - - -	Do.	109
Fringilla carduelis, goldfinch, - - -	Do.	
Corvus corax, raven, - - - - -	Despretz.	
Turdus, thrush, (of Ceylon,) - - -	J. Davy.	
Tetrao perdrix, partridge, - - - -	Pallas.	
Anas clypeata, shoveler, - - - -	Do.	108
Tringa pugnax, ruffe, - - - -	Do.	
Scolopax limosa, lesser godwit, - - -	Do.	
Tetrao tetrix, grouse, - - - -	Do.	
Fringilla brumalis, winter finch, - -	Do.	
Loxia pyrrhula, - - - - -	Do.	
Falco nisus, sparrowhawk, - - -	Do.	
Vultur Barbatus, - - - - -	Do.	
Anser pulchricollis, - - - - -	Do.	107
Colymbus auritus, dusky grebe, - - -	Do.	
Tringa vanellus, lawping, (wounded) -	Do.	
Tetrao lagopus, ptarmigan, - - -	Do.	
Fringilla domestica, house sparrow, - -	Do.	107 to 111
Strix passerina, little owl, - - -	Do.	106
Hæmatopus ostralegus, sea pie - - -	Do.	
Anas penelope, wigeon, - - - -	Do.	
Anas strepera, gadwall, - - - -	Do.	
Pelecanus carbo, - - - - -	Do.	

Falco ossifragus, sea eagle,	Pallas.	105
Fulica atra, coot,	Do.	
Anas acuta, pintail duck,	Do.	
Falco milvus, kite, (wounded)	Do.	104
Merops apiaster, bee eater,	Do.	
Goose,	Martine.	103 to 107
Hen,	Do.	
Dove,	Do.	
Duck,	Do.	
Ardea stellaris,	Pallas.	103
Falco albicollis,	Do.	
Picus major,	Do.	
Cossus ligniperda,	Schultze.	89 to 91
Shark,	I. Davy.	83
Torpedoo Marmorata,	Rudolphi.	74

According to the above table, it will be observed, that the inhabitants of the Arctic regions—whether belonging to the class of mammalia or birds—are among those whose temperature is highest. That of the Arctic fox is, indeed, probably higher than the amount given in the table, being taken after death, when the temperature of the air was low as—14° of Fahrenheit, and when loss of heat may be supposed to have taken place rapidly.

The temperature of the smaller insects it is, of course, impracticable to indicate; but we can arrive at an approximation in those that congregate in masses, as the bee and the ant; for it is impossible to suppose, with Maraldi, that the augmented temperature is dependent upon the motion and friction of the wings and bodies of the busy multitudes. Juch found that, when the temperature of the atmosphere was—18° of Fahrenheit, that of a hive of bees was 44°; and, in an ant-hill, the thermometer stood at 68° or 70°, when the temperature of the air was 55°; and at 75°, when that of the air was 66°; and Hausmann and Renger saw the thermometer rise, when put into narrow glasses in which they had put scarabæi and other insects.

The power of preserving their temperature within certain limits is not, however, possessed exclusively by animals. The heat of a tree, examined by Mr. Hunter, was found to be always several degrees higher than that of the atmosphere, when the temperature of the air was below 56° of Fahrenheit; but it was always several degrees below it when the weather was warmer. Some plants develope a considerable degree of heat, during the period of blooming. This was first noticed by Lamarck in the *arum italicum*. In the *Arum cordifolium*, of the Isle of Bourbon, Hubert found, when the temperature of the air was 80°, that of the spathe or sheath as high as 134°; and Bory De St. Vincent observed a similar elevation, although in a less degree, in the *Arum esculentum*, *esculent arum* or *Indian kale*.

The animal body is so far influenced by external heat, as to rise or fall with it; but the range, as we have already remarked, is

limited in the warm-blooded animal,—more extensive in the cold-blooded. Dr. Currie found the temperature of a man plunged into sea-water at 44° sink, in the course of a minute and a half after immersion, from 98° to 87°; and, in other experiments, it descended as low as 85°, and even as 83°. It was always found, however, that, in a few minutes, the heat approached its previous elevation; and, in no instance, could it be depressed lower than 83°, or 15° below the temperature at the commencement of the operation. Similar experiments have been performed on other warm-blooded animals. Hunter found the temperature of a common mouse to be 99°, when that of the atmosphere was 60°; when the same animal was exposed, for an hour, to an atmosphere of 15°, its heat had sunk to 83°; but the depression could be carried no farther. He found, also, that a dormouse,—whose heat in an atmosphere at 64°, was 81½°,—when put into air, at 20°, had its temperature raised, in the course of half an hour to 93°; an hour after, the air being at 30°, it was still 93°; another hour after, the air being at 19°, the heat of the pelvis was as low as 83°,—an experiment, which strongly proves the great counteracting influence exerted, when animals are exposed to an unusually low temperature. In this experiment, the dormouse had maintained its temperature about 70° higher than that of the surrounding medium, and for the space of two hours and a half.

In the hybernating torpid quadrupeds the reduction of temperature, during their torpidity, is considerable. Jenner found the temperature of a hedge-hog, in the cavity of the abdomen, towards the pelvis, to be 95°, and that of the diaphragm 97° of Fahrenheit, in summer, when the thermometer in the shade stood at 78°; whilst in winter, the temperature of the air being 44, and the animal torpid, the heat in the pelvis was 45°, and of the diaphragm 48½°. When the temperature of the atmosphere was at 26°, the heat of the animal, in the cavity of the abdomen, where an incision was made, was reduced as low as 30°; but—what singularly exhibits the power possessed by the system of regulating its temperature,—when the same animal was exposed to the cold atmosphere of 26° for two days, its heat, in the rectum, was raised to 93°, or 67° above that of the atmosphere. At this time, however, it was lively and active, and the bed, on which it lay, felt warm.

In the cold-blooded animal, we have equal evidence of the generation of heat. Hunter found, that the heat of a viper, placed in a vessel at 10°, was reduced, in ten minutes, to 37°; in the next ten minutes, the temperature of the vessel being 13°, it fell to 35°; and in the next ten minutes, the vessel being at 20°, to 31°. In frogs, he was able to lower the temperature at 31°; but beyond this point it was not possible to lessen the heat, without destroying the animal.

In the Arctic regions, the animal temperature appears to be steadily maintained, notwithstanding the intense cold that prevails;

and we have already seen, that the animals of those hyperborean latitudes possess a more elevated temperature than those of more genial climes. In the enterprizing voyages, undertaken by the British government for the discovery of a north-west passage, the crews of the ships were frequently exposed to a temperature of —40° or—50° of Fahrenheit's scale; and the same thing happened during the disastrous campaign of Russia in 1812, in which so many of the French army perished from cold. During the second voyage of Captain Parry, the following temperatures of animals, immediately after death, were taken principally by Captain Lyon.

		Temperature of the Animal.	Temperature of the Atmosphere.
1821			
Nov. 15.	An Arctic fox	$106\frac{3}{4}$°	— 14°
Dec. 3.	Do.	$101\frac{1}{2}$	— 5
	Do.	100	— 3
11.	Do.	$101\frac{1}{4}$	— 21
15.	Do.	$99\frac{3}{4}$	— 15
17.	Do.	98	— 10
19.	Do.	$99\frac{3}{4}$	— 14
1822.			
Jan. 3.	Do.	$104\frac{1}{2}$	— 23
9.	A white hare	101	— 21
10.	An Arctic fox	100	— 15
17.	Do.	106	— 32
24.	Do.	103	— 27
	Do.	103	— 27
	Do.	102	— 25
27.	Do.	101	— 32
Feb. 2.	A wolf	105	— 27

These animals must, therefore, have to maintain a temperature at least 100° higher than that of the atmosphere, throughout the whole of winter; and it would appear as if the counteracting energy becomes proportionately greater as the temperature is more depressed. It is, however, a part of their nature to be constantly eliciting this unusual quantity of caloric, and therefore they do not suffer. Where animals, not so accustomed, are placed in an unusually cold medium, the efforts of the system rapidly exhaust the nervous energy; and when this becomes so far depressed as to interfere materially with the function of calorification, which we shall find is to a certain extent under the nervous influence, the temperature sinks and the individual dies lethargic—or, as if struck with apoplexy.

The ship Endeavour, being on the coast of Terra del Fuego, on the 21st of December, 1769, Messrs. Banks, Solander, and others were desirous of making a botanical excursion upon the hills on the coast, which did not appear to be far distant. The party, consisting of eleven persons, were overtaken by night on the hills during extreme cold. Dr. Solander who had crossed the mountains which

divide Sweden from Norway, knowing the almost irresistible desire for sleep produced by exposure to great cold, more especially when united with fatigue, enjoined his companions to keep moving, whatever pains it might cost them, and whatever might be the relief promised by an indulgence in rest. "Whoever sits down," said he, "will sleep, and whoever sleeps will wake no more." Thus admonished, they set forward, but whilst still upon the bare rock, and before they had got among the bushes, the cold suddenly became so severe as to produce the effects that had been dreaded. Dr. Solander himself was the first who found the desire irresistible, and insisted on being suffered to lie down. Mr. Banks, (afterwards Sir Joseph,) entreated and remonstrated in vain. The doctor lay down upon the ground, although it was covered with snow; and it was with the greatest difficulty, that his friend could keep him from sleeping. Richmond, one of the black servants, began to linger and to suffer from the cold, in the same manner as Dr. Solander. Mr. Banks, therefore, sent five of the company forward to get a fire ready at the first convenient place they came to; and himself, with four others, remained with the doctor and Richmond, whom, partly by persuasion and partly by force, they carried forward; but when they had got through the birch and swamp, they both declared they could go no farther. Mr. Banks had again recourse to entreaty and expostulation, but without effect. When Richmond was told, that if he did not go on, he would, in a short time, be frozen to death, he answered, that he desired nothing but to lie down and die. Dr. Solander was not so obstinate, but was willing to go on, if they would first allow him to take some sleep, although he had before observed, that to sleep was to perish. Mr. Banks and the rest of the party found it impossible to carry them, and they were consequently suffered to sit down, being partly supported by the bushes, and, in a few minutes, they fell into a profound sleep. Soon after, some of the people, who had been sent forward, returned with the welcome intelligence, that a fire had been kindled about a quarter of a mile farther on the way. Mr. Banks then endeavoured to rouse Dr. Solander, and happily succeeded, but, although he had not slept five minutes, he had almost lost the use of his limbs, and the soft parts were so shrunk, that his shoes fell from his feet. He consented to go forward with such assistance as could be given him, but no attempts to relieve Richmond were successful. He, with another black left with him, died. Several others began to lose their sensibility, having been exposed to the cold near an hour and a half, but the fire recovered them.

The preceding history is interesting in another point of view besides the one for which it was more especially adduced. Both the individuals, who perished, were blacks, and it has been a common observation, that they bear exposure to great heat with more impunity, and suffer more from intense cold, than the white variety of

the species. As regards inorganic bodies, it has been satisfactorily shown, that the phenomena of the radiation of caloric are connected with the nature of the radiating surface; and that those surfaces, which radiate most, possess, in the highest degree, the absorbing power; in other words, bodies that have their temperatures most readily raised by radiant heat are those that are most easily cooled by their own radiation. In the experiments of Professor Leslie it was found, that a clean metallic surface produced an effect upon the thermometer equal to 12; but when covered with a thin coat of glue its radiating power was so far increased as to produce an effect equal to 80; and, on covering it with lamp-black, it became equal to 100. We can thus understand why, in the negro, there should be a greater expense of caloric than in the white, owing to the greater radiation; not because as much caloric may not have been elicited as in the white. In the same manner we can understand that, owing to the greater absorbing power of his skin, he may suffer less from excessive heat than the white; and this is perhaps the great use of the dark rete mucosum. To ascertain, whether such be the fact, the following experiments were instituted by Sir Everard Home. He exposed the back of his hand to the sun at twelve o'clock, with a thermometer attached to it, another thermometer being placed upon a table with the same exposure. The temperature, indicated by that on his hand, was 90°; by the other, 102°. In forty-five minutes, blisters arose, and coagulable lymph was thrown out. The pain was very severe. In a second experiment, he exposed his face, eyelids, and the back of his hand to water heated to 120°; in a few minutes, they became painful; and, when the heat was farther increased, he was unable to bear it; but no blisters were produced. In a third experiment, he exposed the backs of both hands, with a thermometer upon each, to the sun's rays. The one hand was uncovered; the other had a covering of black cloth, under which the ball of the thermometer was placed. After ten minutes, the degree of heat of each thermometer was marked, and the appearance of the skin examined. This was repeated at three different times. The first time, the thermometer under the cloth stood at 91°, the other thermometer at 85°; the second time, they indicated respectively 94° and 91°; and the third time, 106° and 98°. In every one of these trials, the skin, that was uncovered, was scorched, whilst the other had not suffered in the slightest degree.

From all his experiments, Sir Everard concludes, that the power of the sun's rays to scorch the skin of animals is destroyed, when applied to a black surface; although the absolute heat, in consequence of the absorption of the rays, is greater.

When cold is applied to particular parts of the body, the heat of those parts sinks lower than the minimum of depressed temperature. Although Hunter was unable to heat the urethra one degree above the maximum of elevated temperature of the body, he succeeded in

cooling it 29° lower than the minimum of depressed temperature, or to 58°. He cooled down the ears of rabbits until they froze; and, when thawed, they recovered their natural heat and circulation. The same experiment was performed on the comb and wattles of a cock. Resuscitation was, however, in no instance practicable where the whole body had been frozen.

The same observer found, that the power of generating heat, when exposed to a cooling influence, was possessed even by the egg. An egg, which had been frozen and thawed, was put into a cold mixture along with one newly laid. The latter was seven minutes and a half longer in freezing than the other. In another experiment, a fresh laid egg, and one which had been frozen and thawed, were put into a cold mixture at 15°; the thawed one soon rose to 32°, and began to swell and congeal; the fresh one sank to 29½, and, in twenty-five minutes after the dead one, it rose to 32°, and began to swell and freeze.

All these facts prove, that when the living body is exposed to a lower temperature than usual, a counteracting power of calorification exists; but that, in the human species, such exposure to cold is incapable of depressing the temperature of the system lower than about 15° beneath the natural standard.

On the other hand, when the living body is exposed to a temperature greatly above the natural standard, an action of refrigeration is exerted; so that the animal heat cannot rise beyond a certain number of degrees;—to a much smaller extent in fact than it is capable of being depressed by the opposite influence.

Boerhaave maintained the strange opinion, that no warm-blooded animal could exist in a temperature higher than that of its own body. In some parts of Virginia, there are days in every summer, in which the thermometer reaches 98° of Fahrenheit; and in other parts of this country, it is occasionally much higher. The meteorological registers show it to be at times as high as 108° at Council Bluffs, in Missouri; at 104°, in New York; and at 100°, in Michigan; whilst in most of the states, on some days of summer, it reaches 96° or 98°. At Sierra Leone, Messrs. Watt and Winterbottom saw the thermometer frequently at 100°, and even as high as 102° and 103°, at some distance from the coast. Adanson saw it at Senegal as high as 108½°. Brydone affirms, that when the sirocco blows in Sicily, the heat rises to 112°. Dr. Chalmers observed a heat of 115° in South Carolina; Humboldt of 110° to 115° in the Llanos or Plains near the Orinoco; and Captain Tuckey asserts, that on the Red Sea he never observed the thermometer at midnight under 94°; at sunrise under 104°; or at midday under 112°. In British India, it is asserted to have been seen as high as 130°.*

* For an account of the highest temperature, observed in different climates, see the Author's 'Elements of Hygiène,' p. 96.

So long ago as 1758, Governor Ellis of Georgia had noticed how little the heat of the body is influenced by the external atmosphere. "I have frequently," he remarks, "walked an hundred yards under an umbrella with a thermometer suspended from it by a thread, to the height of my nostrils, when the mercury has rose to 105°, which is prodigious. At the same time, I have confined this instrument close to the hottest part of my body, and have been astonished to observe, that it has subsided several degrees. Indeed I never could raise the mercury above 97° with the heat of my body." Two years after the date of this communication, the power of resisting a much higher atmospheric temperature was discovered by accident. MM. Duhamel and Tillet,—in some experiments for destroying an insect, that infested the grain of the neighbourhood,—having occasion to use a large public oven, on the same day in which bread had been baked in it, were desirous of ascertaining its temperature. This they endeavoured to accomplish by introducing a thermometer into the oven at the end of a shovel. On being withdrawn, the thermometer indicated a degree of heat considerably above that of boiling water; but M. Tillet, feeling satisfied that the thermometer had fallen several degrees in approaching the mouth of the oven, and seeming to be at a loss how to rectify the error, a girl,—one of the servants of the baker, and an attendant on the oven,—offered to enter, and mark with a pencil the height at which the thermometer stood within the oven. The girl smiled at M. Tillet's hesitation at her proposition, entered the oven, and noted the temperature to be 260° of Fahrenheit. M. Tillet, anxious for her safety, called upon her to come out; but she assured him she felt no inconvenience from her situation, and remained ten minutes longer, when the thermometer had risen to 280° and upwards. She then came out of the oven, with her face considerably flushed, but her respiration by no means quick or laborious.

These facts excited considerable interest, but no farther experiments appear to have been instituted, until, in the year 1774, Dr. Geo. Fordyce and Sir Charles Blagden made their celebrated trials with heated air. The rooms, in which these were made, were heated by flues in the floor. Having taken off his coat, waistcoat, and shirt, and being provided with wooden shoes tied on with list, Dr. Fordyce went into one of the rooms, as soon as the thermometer indicated a degree of heat above that of boiling water. The first impression of this heated air upon his body was exceedingly disagreeable; but, in a few minutes, all uneasiness was removed by copious perspiration. At the end of twelve minutes, he left the room very much fatigued, but not otherwise disordered. The thermometer had risen to 220°. In other experiments, it was found, that a heat of even 260° could be borne with tolerable ease. At this temperature, every piece of metal was intolerably hot; small quantities of water, in metallic vessels, quickly boiled; and streams of moisture poured down over the whole surface of his body. That

this was merely the vapour of the room, condensed by the cooler skin, was proved by the fact, that when a Florence flask, filled with water of the same temperature as the body, was placed in the room, the vapour condensed in like manner upon its surface, and ran down in streams. Whenever the thermometer was breathed upon the mercury sank several degrees. Every expiration—especially if made with any degree of violence—communicated a pleasant impression of coolness to the nostrils, scorched immediately before by the hot air rushing against them when they inspired. In the same manner, their comparatively cool breath cooled their fingers, whenever it reached them. "To prove," says Sir Charles Blagden, "that there was no fallacy in the degree of heat, shown by the thermometer, but that the air, which we breathed, was capable of producing all the well-known effects of such an heat on inanimate matter, we put some eggs and beef-steak upon a tin frame, placed near the standard thermometer, and farther distant from the cockle than from the wall of the room. In about twenty minutes, the eggs were taken out roasted quite hard; and, in forty-seven minutes, the steak was not only dressed, but almost dry. Another beef-steak was rather overdone in thirty-three minutes. In the evening, when the heat was still greater, we laid a third beef-steak in the same place; and as it had now been observed, that the effect of the heated air was much increased by putting it in motion, we blew upon the steak with a pair of bellows, which produced a visible change on its surface, and seemed to hasten the dressing: the greatest part of it was found pretty well done in thirteen minutes."

In all these experiments, and similar ones were made in the following year, by Dobson, of Liverpool, the heat of the body, in air of a high temperature, speedily reached 100°; but exposure to 212°, and more, did not carry it higher. These results are not, however, exactly in accordance with those of MM. Berger and De La Roche, deduced from experiments performed in 1806. Having exposed themselves, for some time, to a stove,—the temperature of which was 39° of Réaumur, or 120° of Fahrenheit,—their temperature was raised 3° of Réaumur, or $6\frac{3}{4}$° of Fahrenheit; and M. De La Roche found, that his rose 4° of Réaumur, or 9° of Fahrenheit, when he had remained sixteen minutes in a stove, heated to 176° of Fahrenheit.

According to Sir David Brewster, the distinguished sculptor, Chantry, exposed himself to a temperature yet higher. The furnace which he employs for drying his moulds, is about 14 feet long, 12 feet high, and 12 feet broad. When raised to its highest temperature, with the doors closed, the thermometer stands at 350° and the iron floor is *red-hot.* The workmen often enter it at a temperature of 340°, walking over the iron floor with wooden clogs, which are, of course, charred on the surface. On one occasion, Mr. Chantry, accompanied by five or six of his friends, entered the furnace, and

after remaining two minutes, they brought out a thermometer, which stood at 320°. Some of the party experienced sharp pains in the tips of their ears, and in the septum of the nose, whilst others felt a pain in the eyes.

In some experiments of Chabert, who exhibited his powers as a "Fire-king," in this country as well as in Europe, he is said to have entered an oven with impunity, the heat of which was from 400° to 600° of Fahrenheit.

Experiments have shown, that the same power of resisting excessive heat is possessed by other animals. Drs. Fordyce and Blagden shut up a dog in a room, the temperature of which was between 220° and 236°, for half an hour; at the end of this time, a thermometer was applied between the thigh and flank of the animal; and, in about a minute, the mercury sank to 110°; but the real heat of the body was certainly less than this, as the ball of the thermometer could not be kept a sufficient time in proper contact; and the hair, which felt sensibly hotter than the bare skin, could not be prevented from touching the instrument. The temperature of this animal, in the natural state, is 101°.

We find, in the case of aquatic animals, some astonishing cases of adaptation to the medium in which they live. Although man is capable of breathing air, heated to above the boiling point of water with impunity, we have seen, that he cannot bear the contact of water much below that temperature. Yet we find certain of the lower animals—as fishes—living in water at a temperature, which would be entirely sufficient to boil them if dead. In the thermal springs of Bahia, in Brazil, many small fishes are seen swimming in a rivulet, which raises the thermometer to 88°, when the temperature of the air is only 77½°. Sonnerat, again, found fishes existing in a hot spring at the Manillas, at 158° Fah.; and MM. Humboldt and Bonpland, in travelling through the province of Quito in South America, perceived them thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its explosions, along with water and heated vapour, which raised the thermometer to 210°, or only two degrees short of the boiling point. Dr. Reeve found living larvæ in a spring, whose temperature was 208°; Lord Bute saw confervæ and beetles in the boiling springs of Albano, which died when plunged into cold water; and Dr. Elliotson knew a gentleman, who boiled some honeycomb, two years old, and, after extracting all the sweet matter, threw the refuse into a stable, which was soon filled with bees.

When the heating influence is applied to a part of the body only, as to the urethra, the temperature of the part is not increased beyond the degree to which the whole body may be raised.

From all these facts, then, we may conclude, that when the body is exposed to a temperature, greatly above the ordinary standard of the animal, a frigorific influence is exerted; but this is effected at a great expense of the vital energy; and hence is followed by con-

siderable exhaustion, if the effort be prolonged. In the cold-blooded animal, the power of resisting heat is not great; so that it expires in water not hotter than the human blood occasionally is. Dr. Edwards found, that a frog, which can live for eight hours in water at 32°, is destroyed in a few seconds in water at 105°: this appears to be the highest temperature that cold-blooded animals can bear.

Observation has shown, that although the average temperature of an animal is such as we have stated in the table, particular circumstances may give occasion to some fluctuation. A slight difference exists, according to sex, temperament, idiosyncrasy, &c. MM. Edwards and Gentil found the temperature of a young female half a degree less than that of two boys of the same age. Edwards tried the temperature of twenty sexagenarians, thirty-seven septuagenarians, fifteen octogenarians, and five centenarians, at the large establishment of Bicêtre, and he observed a slight difference in each class. John Davy found, that the temperature of a lamb was a degree higher than that of its mother; in five new-born children, the heat was about half a degree higher than that of the mother, and it rose half a degree higher in the first twelve hours after birth. Edwards, on the other hand, found, that, in the warm-blooded animal, the faculty of producing heat is less, the nearer to birth; and that in many cases, as soon as the young dropped from the mother, the temperature fell to within a degree or two of that of the circumambient air; and he moreover affirms, that the faculty of producing heat is at its minimum at birth, and that it increases successively to the adult age. His trials on children, at the large *Hôpital des Enfans* of Paris, and on the aged, at Bicêtre, showed that the temperature of infants, one or two days old, was from 93° to 95° of Fahrenheit; of the sexagenarian from 95° to 97°; of the octogenarian 94° or 95°; and that, as a general rule, it varied according to the age.

In his experiments connected with this subject, he discovered a striking analogy between warm-blooded animals in general. Some of these are born with the eyes closed; others with them open, the former, until the eyes are opened, he found to resemble the cold-blooded animal; the latter—or those born with the eyes open—the warm-blooded. Thus, he remarks, the state of the eyes, although having no immediate connexion with the production of heat, may yet coincide with an internal structure influencing that function, and it certainly furnishes signs, which indicate a remarkable change in this respect; for, at the period of the opening of their eyes, all young mammalia have nearly the same temperature as adults. Now, in accordance with analogy, a new born infant, at the full period, having its eyes open, should have the power of maintaining a pretty uniform temperature during the warm seasons; but, if birth should take place at the fifth or sixth month, the case is altered; the pupil is generally covered with the *membrana pupillaris*, which places the

young being in a condition similar to that of closure of the eyelids in animals. Analogy, then, would induce us to conclude, that, in such an infant, the power of producing heat should be inconsiderable, and observation confirms the conclusion; although we obviously have not the same facilities, as in the case of animals, of exposing the infant to a depressed temperature. The temperature of a seven months' child, though well swathed, and near a good fire, was, within two or three hours after birth, no more than 89.6° Fahrenheit. Before the period at which this infant was born, the *membrana pupillaris* disappears; and it is probable, as Dr. Edwards has suggested, that if it had been born prior to the disappearance of the membrane, its power of producing heat might have been so feeble, that it would scarcely have differed from that of mammalia born with their eyes closed.

The state of the system, as to health or disease, also influences the evolution of heat. Dr. Francis Home, of Edinburgh, took the heat of various patients at different periods of their indispositions. He found that of two persons, labouring under the cold stage of an intermittent, to be 104°; whilst, during the sweat and afterwards, it felt to 101°, and to 99°. The highest degree, which he noticed in fever, was 107°. We have often witnessed the thermometer at 106° in scarlatina and in typhus, but it probably rarely exceeds this, although it is stated to have been seen as high as 112°, and this is the point designated as "fever heat," on Fahrenheits' scale. M. Edwards alludes to a case of tetanus, in a child, communicated to him by M. Prévost of Geneva, in which the temperature rose to 110.75° Fahrenheit. Hunter found the interior of a hydrocele, on the day of operation, to raise the mercury to 92°; on the following day, when inflammation had commenced, it rose to 99°. The fluid, obtained from the abdomen of an individual, tapped for the seventh time for dropsy of the lower belly, indicated a temperature of 101°. Twelve days thereafter, when the operation was repeated for the eighth time, the temperature was 104°. Dr. James Currie had himself bled; and during the operation, the mercury of a thermometer, which he held in his hand, sank, at first slowly and afterwards rapidly, nearly 10°; and when he fainted, the assistant found, that it had sunk 8° farther.

MM. Edwards and Gentil assert, that they have likewise observed diurnal variations in the temperature of individuals, and these produced, apparently, by the particular succession in the exercise of the different organs; as where intellectual meditation was followed by digestion. These variations, they affirm, frequently amounted to two or three degrees, between morning and evening.

Such are the prominent facts connected with the subject of animal heat. It is obvious, that it is altogether disengaged by an action of the sytem, which enables it to counteract, within certain limits, the extremes of atmospheric heat and cold. The animal body, like all other substances, is subjected to the laws regard-

ing the equilibrium, the conduction, and the radiation of caloric; but, by virtue of the important function we are now considering, its own temperature is neither elevated nor depressed by those influences to any great amount.—Into the seat and nature of this mysterious process, and the various ingenious theories, that have been indulged, we will now inquire.

Physiologists have been by no means agreed, regarding the organs or apparatus of calorification. Some, indeed, have affirmed that there is not, strictly speaking, any such apparatus; and that animal heat is a result of all the other vital operations. Amongst those, too, who admit the existence of such an apparatus, a difference of sentiment prevails; some thinking, that it is *local*, or effected in a particular part of the body; others, that it is *general*, or disseminated through the whole of the economy.

Under the name *caloricité* Chaussier admits a primary vital property, by virtue of which living beings disengage the caloric on which their proper temperature is dependent, in the same manner as they accomplish their other vital operations, by other vital properties; and, in support of this doctrine, he adduces the circumstance, that each living body has its own proper temperature; which is coexistent only with the living state; is common to every living part; ceases at death; and augments by every cause, that excites the vital activity. It has been properly objected, however, to this view, that the same arguments would apply equally to many other vital operations,—and that it would be obviously improper to admit, for each of these functions, a special vital principle. The notion has not experienced favour from the physiologist, and is, we believe, confined to the individual from whom it emanated.

Boni, again, according to Adelon, considers that no particular organ is specially charged with the disengagement of caloric; but that it is the common resultant of all the vital actions, nervous or muscular, of digestion, respiration, circulation, nutrition, secretion, &c. The arguments, which he adduces, in favour of his position, are,—that the exercise of any of these functions actually modifies the temperature of the body; that mental labour heats the head,—hence the excitement witnessed in the maniac, and the great resistance to cold for which he is distinguished; and that, during emotion, we are hot or cold, whatever may be the condition of the atmosphere.

The action of the various organs of the body has, doubtless, considerable influence in modifying the disengagement of heat; and it is probable, that it takes place in the different organs, referred to by Boni, but not, perhaps, directly in consequence of the functions they accomplish.

Amongst those, who admit that calorification is a local action, some have believed, that the caloric is disengaged in a particular organ, whence it is distributed to every part of the body; whilst others conceive, that every part disengages its own caloric and has its special temperature.

So striking a phenomenon as animal temperature could not fail to attract early attention; and, accordingly, we find amongst the ancients various speculations on the subject. The most prevalent was, that its seat is in the heart; that the heat is communicated to the blood in that viscus, and is afterwards sent to every part of the system; and that the great use of respiration is to cool the heart; but this hypothesis is liable to all the objections, which apply to the notion of any organ of the body acting as a furnace,—that such organ ought to be calcined; and it has the additional objection, applicable to all the speculations, regarding the ebullition and effervescence of the blood as a cause of heat, that it is purely conjectural, without the slightest fact or argument in its favour. It was not, indeed, until the chymical doctrines prevailed, that anything like argument was adduced in support of the local disengagement of heat: the opinions of physiologists then settled almost universally upon the lungs; and this, chiefly, in consequence of the observation, that animals, which do not breathe, have a temperature but little superior to the medium in which they live; whilst man, and animals that breathe, have a temperature considerably higher than the medium heat of the climate in which they exist, and one which is but little affected by changes in the thermal condition of that medium; and, moreover, that birds, which breathe, in proportion, a greater quantity of air than man, have a still higher temperature than he.

Mayow, whose theory of animal heat was, in other respects, sufficiently unmeaning, affirmed, that the effect of respiration is not to cool the blood, as had been previously maintained, but to generate heat, which it did by an operation analogous to combustion. It was not, however, until the publication of Dr. Black's doctrine on latent heat, that any plausible explanation of the phenomenon appeared. According to that distinguished philosopher, a part of the latent heat of the inspired air becomes sensible; consequently, the temperature of the lungs, and of the blood passing through them, must be elevated; and, as the blood is distributed to the whole system, it communicates its heat to the parts as it proceeds in its course. But this view was liable to an obvious objection, which was, indeed, fatal to it, and so Black himself appears to have thought, from his silence on the subject. If the whole of the caloric were disengaged in the lungs, as in a furnace, and were distributed through the blood-vessels, as heated air is transmitted along conducting pipes, the temperature of the lungs ought to be much greater than that of the parts more distant from the heart; so great, indeed, as to consume that important organ in a short space of time.

The doctrine, maintained by Lavoisier and Séguin, was;—that the oxygen of the inspired air combines with the carbon and hydrogen of the venous blood, and produces combustion. The caloric, given off, is then taken up by the blood-vessels, and is distributed over the body. The arguments, which they adduced in favour of

this view, were:—the great resemblance between respiration and combustion so that if the latter gives off heat, the former ought to do so likewise;—the fact that arterial blood is somewhat warmer than venous;—certain experiments of Lavoisier and La Place, which consisted in placing animals in the calorimeter, and comparing the quantity of ice which they melted,—and, consequently, the quantity of heat, which they gave off,—with the quantity of carbonic acid produced; and finding, that the quantity of caloric which would result from the carbonic acid formed, was exactly that disengaged by those animals. Independently, however, of other objections, this hypothesis is liable to those already urged against that of Black, which it closely resembles.

The objection, that the lungs ought to be much hotter than they really are—both absolutely and relatively—was attempted to be obviated by Dr. Crawford, in a most ingenious and apparently logical manner. The oxygen of the inspired air, according to him, combines with the carbon given out by the blood, so as to form carbonic acid. But the specific heat of this is less than that of oxygen; and, accordingly, a quantity of latent caloric is set free; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the water—which was supposed to be formed by the union of the hydrogen and the oxygen—in the state of vapour, and to raise the temperature of the inspired air considerably. So far the theory of Crawford was liable to the same objections as those of Black, and Lavoisier and Séguin. He affirmed, however, that the same process, by which the oxygen of the inspired air is converted into carbonic acid, converts likewise the venous into arterial blood; and as he assumed from his experiments, that the capacity for caloric of arterial blood is greater than that of venous, in the proportion of 1.0300 to 0.8928; he conceived, that the caloric, set free in the formation of the carbonic acid, in place of raising the temperature of the arterial blood, is employed in saturating its increased capacity, and in maintaining its temperature at the same degree with the venous.

According to this view, therefore, the heat is not absolutely set free in the lungs, although arterial blood contains a greater quantity of caloric than venous; but when, in the capillaries, the arterial becomes converted into venous blood, or into blood of a less capacity for caloric, the heat is disengaged, and occasions the temperature of the body.

If the facts, which served as a foundation for this beautiful theory of animal heat, were not false, the deductions would be irresistible; and, accordingly, it was, at one time, almost universally received, especially by those who consider that all vital operations can be assimilated to chymical processes. But numerous objections arise against it. In the first place, we have elsewhere endeavoured to show that respiration is not a combustion; and that our know-

ledge is limited to the fact, that oxygen is taken into the pulmonary vessels and carbonic acid given off, but we have no means of knowing whether the one goes immediately to the formation of the other. Dr. Crawford had inferred, from his experiments, that the specific heat of oxygen is 4.7490; of carbonic acid, 1.0454; of azote, 0.7936; and of atmospheric air, 1.7900; but the more recent experiments of De La Roche and Bérard, make that of oxygen, 0.2361; of carbonic acid, 0.2210; of azote, 0.2754; and of atmospheric air, 0.2669; a difference of such a trifling amount, that it has been conceived the quantity of caloric, given out by oxygen during its conversion into carbonic acid, would be insufficient to heat the residual air, which is expelled in breathing, to its ordinary elevation. *Secondly.* The elevation of temperature of one or two degrees, which appears to take place in the conversion of venous into arterial blood, although generally believed in, is not assented to by all. The experiments instituted on this point have been few and imprecise. *Thirdly.* M. Dulong,—on repeating the experiments of Lavoisier and La Place, for comparing the quantities of caloric given off by animals, in the calorimeter, with that which would result from the carbonic acid, formed during the same time in their respiration,—did not attain a like result. The quantity of caloric, disengaged by the animal was always superior to that which would result from the carbonic acid formed. *Fourthly.* The estimate of Crawford, regarding the specific heat of venous and arterial blood, has been contested. He made that of the former, we have seen, 0.8928; of the latter, 1.0300. The result of the experiments of Dr. John Davy give 0.903 to the former, and 0.913 to the latter; and in another case, the result of which has been adopted by Magendie, the specific heat of the venous was greater than that of the arterial blood, in the proportion of .852 to .839. Granting, however, that the case is as stated by Crawford, it is insufficient to explain the phenomena. Legallois has, indeed, attempted to show, that if the whole of the caloric, set free in the manner mentioned, were immediately absorbed, it would be insufficient for the constitution of the arterial blood; and that, instead of the lung running the risk of being calcined, it would be threatened with congelation.

But the theory of Crawford was most seriously assailed by other experiments, tending to show, that the function of calorification is derived from the great nervous centres. When an animal is decapitated, or when the spinal marrow, or the brain, or both, are destroyed, the action of the heart may be still kept up, provided the lungs be artificially inflated. In such case, it is found, that the usual change in the blood, from venous to arterial, is produced; and that oxygen is absorbed and carbonic acid exhaled as usual. Sir Benjamin Brodie, in performing this experiment, directed his attention to the point, whether animal heat is, under such circumstances, evolved, and the temperature maintained, as where the brain and

spinal marrow are entire; and he found, that although the blood appeared to undergo its ordinary changes, the generation of animal heat seemed to be suspended; and, consequently, if the inspired air happened to be colder than the body, the effect of respiration was to cool the animal; so that an animal, on which artificial respiration was kept up, became sooner cold than one killed at the same time and left undisturbed.

The inference, deduced from these experiments, was, that instead of circulation and respiration maintaining the heat, they dissipate it; and that as the heat is diminished by the destruction of the nervous centres, its disengagement must be ascribed to the action of those centres, and particularly to that of the encephalon.

M. Chossat has endeavoured to discover the precise part of the nervous system engaged in calorification; but the results of his experiments have not been such as to induce him to refer it exclusively, with Brodie, to the encephalon. He divided the brain, anterior to the pons varolii, in a living animal, so that the eighth pair of nerves were uninjured. Respiration, consequently, continued, and inflation of the lungs was unnecessary. Notwithstanding this serious mutilation, the circulation also went on; and Chossat observed distinctly, that arterial blood circulated in the arteries. Yet the temperature of the animal gradually sank, from 104° Fahr.,—its elevation at the commencement of the experiment,—to 76°, in twelve hours, when the animal died. It seemed manifest to M. Chossat, that, from the time the brain was divided, heat was no longer given off, and the body gradually cooled as it would have done after death. Farther than this, he noticed, that the time, at which the refrigeration occurred most rapidly, was that in which the circulation was most active,—at the commencement of the experiment. In other experiments, M. Chossat paralyzed the action of the brain by a violent concussion, and by injecting a strong decoction of opium into the jugular vein,—keeping up respiration at the same time artificially. The results were the same. From these experiments, he drew the conclusion, that the brain has a direct influence over the production of heat.

His next experiments were directed to the discovery of the medium through which the brain acts,—the eighth pair of nerves, or spinal marrow. He divided the eighth pair of nerves in a dog, and kept up artificial respiration. The temperature sank gradually, and, at the expiration of sixty hours, when the animal died, it was reduced to 68° of Fahrenheit. Yet death did not occur from asphyxia or suspension of the phenomena of respiration, as the lungs crepitated, exhibited no signs of infiltration, and were partly filled with arterial blood. It appeared to M. Chossat to expire from cold. As, however, the mean depression of heat was less than in the preceding experiments, he inferred, that a slight degree of heat is still disengaged after the section of the eighth pair, whilst, after injury done to the brain directly, heat is no longer given off.

Again, he divided the spinal marrow beneath the occiput, and although artificial respiration was maintained, as in the experiments of Brodie, the temperature gradually fell, and the animal died ten hours afterwards, at a heat of 79°; and as death occurred in this case so much more speedily than in the last, he inferred, that the influence of the brain over the production of heat is transmitted rather by the spinal marrow than by the eighth pair of nerves. In his farther experiments, Chossat found, that when the spinal marrow was divided between each of the twelve dorsal vertebræ, the depression of temperature occurred less and less rapidly, the lower the intervertebral section, and it was imperceptible at the lowest; he therefore concluded, that the spinal marrow did not act directly in the function, but indirectly through the trisplanchnic nerve. To satisfy himself on this point, he opened a living animal on the left side, beneath the twelfth rib, and removed the suprarenal capsule of that side, dividing the trisplanchnic where it joins the semilunar plexus. The animal gradually lost its heat, and died ten hours afterwards in the same state, as regarded temperature, as when the spinal marrow was divided beneath the occiput.

Desiring to obtain more satisfactory results,—the last experiment applying to only one of the trisplanchnic nerves,—he tied the aorta, which supplies both with the materials on which they operate, beneath the place where it passes through the arch of the diaphragm, at the same time preventing asphyxia by inflating the lungs. The animal lost its heat much more rapidly, and died in five hours. In all these cases, according to Chossat, death occurred from cold; the function, by which the caloric, constantly abstracted from the system by the surrounding medium, is generated, having been rendered impracticable. To obtain a medium of comparison, he killed several animals by protracted immersion in cold water, and found, that the lowest temperature, to which the warm-blooded could be reduced, and life persist, was 79° of Fahrenheit. M. Chossat also alludes to cases of natural death by congelation, which he conceives to destroy in the manner we have before suggested, by diminution of the nervous energy, as indicated by progressive stupor, and by debility of the chief functions of the animal economy.

Lastly:—on killing animals suddenly, and attending to the progress of refrigeration after death, he found it to be identical with that which follows direct injury of the brain, or division of the spinal marrow beneath the occiput.

A view, somewhat analogous to this of M. Chossat, has been embraced by Sir Everard Home. He conceives, that the phenomenon is restricted to the ganglionic part of the nervous system, and he rests the opinion chiefly upon the position, that there are certain animals, which have a brain, or some part equivalent to one; but whose temperature is not higher than that of the surrounding medium; whilst, on the other hand, all the animals that evolve heat are provided with ganglia.

The doctrines of Brodie and Chossat have been considered by the generality of the chymists,—by Brande, Thomson, and Paris,—as completely subversive of the chymical doctrines, which refer the production of animal heat to the respiratory function; and their position,—that it is a nervous function,—has seemed to be confirmed, by the facts attendant upon injury done to the nerves of parts; and by what is witnessed in paralytic limbs, the heat of which is generally and markedly inferior to that of the sound parts. But there are many difficulties in the way of admitting, that the nervous system is the special organ for the production of animal temperature. Dr. Wilson Philip, from a repetition of the experiments of Sir Benjamin Brodie, was led to conclude, that the cause, why the temperature of the animal body diminished more rapidly, when artificial inflation was practised, than when the animal was left undisturbed, was owing to too large a quantity of air having been sent into the lungs; and he found, that when a less quantity was used, the cooling process was sensibly retarded by the inflation. The experiments of Legallois, Hastings, and Williams, although differing from each other in certain particulars, corroborate the conclusion of Dr. Philip, and, what is singular, would appear to show, that the temperature occasionally *rises* during the experiment; facts, which would rather confirm the view, that respiration is greatly concerned in the evolution of heat.

Many of the facts, detailed by Chossat, are curious, and exhibit the indirect agency of the nervous system, but his conclusion, that the trisplanchnic is the great organ for its developement, is liable to the objections we have urged regarding the theory, which looks upon the heart, or the lungs as furnaces for the disengagement of caloric, that they ought to be consumed in a short space of time by the operation.

All the facts, however, exhibit, that, in the upper classes of animals, the three great acts of innervation, respiration and circulation are indirectly concerned in the function; not that any one is the special apparatus. M. Edwards has attempted to show, that it is more connected with the second of these than with either of the others. Thus, animals, whose temperature is highest, bear privation of air the least; whilst cold-blooded animals suffer comparatively little from it; and young animals are less affected by it than the adult. Now, the greater the temperature of the animal, and the nearer to the adult age, the greater is the consumption of oxygen. He farther observed, that whilst the seasons modify calorification, they affect also respiration; and that if, in summer, less heat is elicited, and in winter more, respiration consumes less oxygen in the former season than in the latter.

The experiments of Legallois, as well as those instituted by Edwards, led the latter to infer, that there is a certain ratio between heat and respiration, in both cold-blooded and warm-blooded animals, and in hibernating animals, both in the periods of torpidity

and of full activity. When the eighth pair of nerves is divided in the young of the mammalia, a considerable diminution is produced in the opening of the glottis; so that in puppies, recently born, or one or two days old, so little air enters the lungs, that when the experiment is made in ordinary circumstances, the animal perishes as quickly as if it was entirely deprived of air. It lives about half an hour. But, if the same operation be performed upon puppies of the same age, benumbed with cold, they will live a whole day. In the first case, M. Edwards thinks, and plausibly, the small quantity of air is insufficient to counteract the effect of the heat; whilst, in the other, it is sufficient to prolong life considerably, and he deduces the following practical inferences applicable to the adult age, and particularly to man.

A person is asphyxied by an excessive quantity of carbonic acid in the air he breathes; the pulse is no longer perceptible; the respiratory movements cannot be discerned, but his temperature is still elevated. How should we proceed to recall life? Although the action of the respiratory organs is no longer visible, all communication with the air is not cut off. The air is in contact with the skin, upon which it exerts a vivifying influence: it is also in contact with the lungs, in which it is renewed by the agitation constantly taking place in the atmosphere, and by the heat of the body, which rarefies it. The heart continues to beat, and maintains a certain degree of circulation, although not perceptible by the pulse. The temperature of the body is too high to allow the feeble respiration to produce upon the system all the effect of which it is capable. The temperature must then be reduced; the patient must be withdrawn from the deleterious atmosphere; be stripped of his clothes, in order that the air may have a more extended action upon his skin; be exposed to the cold, although it be winter, and cold water be thrown upon his face, until the respiratory movements reappear. This is precisely the treatment adopted in practice to revive an individual from a state of asphyxia. If, instead of cold, continued warmth were to be applied, it would be one of the most effectual means of extinguishing life. This consequence, like the former, is confirmed by experience. In sudden faintings, when the pulse is weak or imperceptible, the action of the respiratory organs diminished, and sensation and voluntary motion suspended, persons, the most ignorant of medicine, are aware, that means of refrigeration must be employed,—such as exposure to air, ventilation, and sprinkling with cold water. In violent attacks of asthma, also, when the extent of respiration is so limited, that the patient experiences a sense of suffocation, he courts the cold air even in the severest weather; opens the windows; breathes a frosty air, and finds himself relieved.

As a general rule, an elevated temperature accelerates the respiratory movements, but the degree of temperature, requisite to produce this effect, is not the same in all. The object of this is, that

more air may come in contact with the lungs, in a given time, so as to reanimate what the heat depresses.

It is proper to remark, however, that we meet with many exceptions to the rule endeavoured to be laid down by M. Edwards, as regards the constant ratio between heat and respiration. In the 5th volume of the 'Dublin Hospital Reports,' Drs. Graves and Stokes give the case of a patient, who laboured under a very extensive developement of tubercles, had tubercular abscesses on the upper portions of both lungs, and general bronchitis. In this case, at a period when the skin was hotter than usual, and the pulse 126, the respirations were only 14 in the minute; besides, as Dr. Alison has remarked, the temperature of the body is not raised by voluntarily increasing or quickening the acts of respiration; but by voluntary exertions of other muscles, which accelerate the circulation, and thus necessitate an increased frequency of respiration; a fact, which would seem to show, that calorification is dependent not simply on the application of oxygen to the blood, but on the changes that take place during circulation, and to the maintenance of which, the oxygenation of the blood is one essential condition. Moreover, in the fœtus in utero, there is, of course, no respiration; yet its temperature is said to even exceed that of the mother; and we know, that its circulation is more rapid, and its nutrition more active.

That innervation is indirectly concerned in the phenomenon is proved by the various facts which have been referred to; and Legallois, although he does not accord with Sir B. Brodie, conceives, that the temperature is greatly under the influence of the nervous system, and that whatever weakens the nervous power, proportionally diminishes the capability of producing heat. Dr. Philip, too, concluded from his experiments, that the nervous influence is so intimately connected with the power of evolving heat, that it must be looked upon as a necessary medium between the different steps of the operation. He found, that if the galvanic influence be applied to fresh drawn arterial blood, an evolution of heat, amounting to three or four degrees, takes place, whilst the blood assumes the venous hue and becomes partly coagulated. He regards the process of calorification as a secretion; and explains it upon his general principle of the identity of the nervous and galvanic influences, and of the necessity for the exercise of such influence in the function of secretion.

Again, that the circulation is necessary to calorification, we have evidence in the circumstance, that if the vessels, proceeding to a part, be tied, animal heat is no longer disengaged from it.

It is manifest, then, that in animals, and especially in the warm-blooded, the three great vital operations are necessary for the disengagement of the due temperature, but we have no sufficient evidence of the direct agency of any one, whilst we see heat elicited in the vegetable, in which these functions are at all events rudi-

mental; and the existence of one of them—innervation—more than doubtful.

The view of those, who consider, that the disengagement of caloric occurs in the capillary system of the whole of the body, appears to us the most consistent with observed phenomena. These views have varied according to the physical circumstances, that have been looked upon as producing heat. By some, it has been regarded as the product of an effervescence of the blood and humours; by others, as owing to the disengagement of an igneous matter, or spirit from the blood; by others, to an agitation of the sulphureous parts of the blood; whilst Boerhaave and Douglas ascribe it to the friction of the blood against the parietes of the vessels, and of the globules against each other. In favour of the last hypothesis, it was urged, that animal heat is in a direct ratio with the velocity of the circulation, the circumference of the vessels, and the extent of their surface; and that thus we are able to explain, why the heat of parts decreases in a direct ratio with their distance from the heart; and they accounted for the greater heat of the arterial blood, in the lungs, by the supposition, that the pulmonary circulation is far more rapid. Most of these notions are entirely hypothetical. The data are generally incorrect, and the deductions characteristic of the faulty physics of the period in which they were indulged.

The correct view, it appears to us, is that embraced by, perhaps, the generality of physiologists, who admit the caloric to be disengaged in every part, by a special action, under the nervous influence, and the presence of arterial blood; the latter either furnishing the materials, or merely acting as a stimulus. In this manner, calorification becomes, like nutrition, a function executed in the capillary system, and therefore appropriately considered in this place.

It has been remarked by Tiedemann, that the intussusception of alimentary matters, and their assimilation by digestion and respiration, the circulation of the humours, nutrition and secretion, the renewal of materials accompanying the exercise of life, and the constant changes of composition in the solid and liquid parts of the organism,—all of which are under the nervous influence,—participate in the evolution of heat, and we deceive ourselves when we look for the cause in one of those acts only.

It is by this theory of the general evolution of caloric in the capillary system, that we are capable of accounting for the increased heat that occurs in certain local diseases, in which the temperature exceeds, by several degrees, that of the blood in the large vessels. By some, it has been doubted, whether, in cases of local inflammation, any such augmentation of temperature exists, but the error seems to have arisen from the temperature of the part, in health, having generally been ranked at blood heat; whereas, we shall find, that it differs essentially in different parts. Dr. Thomson found.

that a small inflamed spot, in his right groin, gave out, in the course of four days, a quantity of heat, sufficient to have heated seven wine-pints of water from 40° to 212°; yet the temperature was not sensibly less than that of the rest of the body at the end of the experiment, when the inflammation had ceased.

Of the mode, in which heat is evolved in the capillaries, it is impossible for us to arrive at any satisfactory information. The result alone indicates, that the process has been accomplished. In the present state of our knowledge, we are compelled to refer it to some vital action, of the nature of which we are ignorant; but which seems to be possessed by all organized bodies,—vegetable as well as animal.

By supposing, that calorification is effected in every part of the body, we can understand why different portions should have different temperatures; as the activity of the function may vary, in this respect, according to the organ. Chopart and Dessault found the heat of the rectum to be 100°; of the axilla and groin, when covered with clothes, 96°; and of the chest 92°. Dr. Davy found the temperature of a naked man, just risen from bed, to be 90° in the middle of the sole of the foot; 93° between the inner ancle and tendo Achilles; 91.5° in the middle of the shin; 93° in the calf; 95° in the ham; 91° in the middle of the thigh; 96.5° in the fold of the groin; 95° at three lines beneath the umbilicus; 94° on the sixth rib of the left side; 93° on the same rib of the right side; and 98° in the axilla. MM. Edwards and Gentil found the temperature of a strong adult male, to be, in the rectum and mouth, 102°; on the hands, 100°; in the axillæ and groins, 98°; on the cheeks, 97°; and on the prepuce and the feet, 96°; and on the chest and abdomen 95°.

All these experiments, it is obvious, concern only the temperature of parts, which can be readily modified by the circumambient medium. To judge of the comparative temperature of the internal organs, Dr. Davy killed a calf, and noted the temperature of different parts, both external and internal. The blood of the jugular vein raised the thermometer to 105.5°; that of the carotid artery to 107°. The heat of the rectum was 105.5°; of the metatarsus 97°; of the tarsus 90°; of the knee 102°; of the head of the femur 103°; of the groin 104°; of the under part of the liver 106°; of the substance of that organ 106°; of the lung 106.5°; of the left ventricle 107°; of the right 106°; and of the substance of the brain 104°.

In the case of fistulous opening, observed by Dr. Beaumont, the thermometer indicated a difference of three-fourths of a degree between the splenic and pyloric orifices of the stomach; the temperature of the latter being more elevated.

It is not easy to account for these differences without supposing that each part has the power of disengaging its own heat, and that the communication of caloric is not sufficiently ready to prevent the difference from being perceptible.

It was stated, early in this section, that man possesses the power of resisting cold as well as heat within certain limits, and of preserving his temperature greatly unmodified. Let us inquire into the direct and indirect agents of these counteracting influences.

As the mean temperature of the warmest regions does not exceed 85° of Fahrenheit, it is obvious, that he must be constantly disengaging caloric to the surrounding medium:—still his temperature remains the same. This is effected by the mysterious agency which we have been considering, materially aided, however, by several circumstances both intrinsic and extrinsic to the system.

The external envelope of the body is a bad conductor of caloric, and therefore it protects the internal organs, to a certain extent, from the sudden influence of excessive heat or cold. But the cutaneous system of man is a much less efficient protection than that of animals. In the warm-blooded animals, in general, the bodies are covered with hair or feathers. The whale is destitute of hair; but, besides the protection, which is afforded by the extraordinary thickness of its skin, and the stratum of fat,—a bad conductor of caloric,—with which the skin is lined, as the animal constantly resides in the water, it is not subjected to the same vicissitudes of temperature as land animals. The seals, bears and walruses, which seek their food in the same seas, sleep on land. They have a coating of hair to protect them. In the case of some of the birds of the genus *Anas*, of northern regions, we meet with a singular anomaly,—the whole of the circumference of the anus being devoid of feathers; but, to make amends for this deficiency, the animal has the power of secreting an oleaginous substance, with which the surface is kept constantly smeared.

It may be remarked that we do not find the quantity of feathers on the bodies of birds to be proportionate to the cold of the climates in which they reside, as is pretty universally the case regarding the quantity of hair on the mammalia.

Man is compelled to have recourse to clothing, for the purpose of preventing the sudden abstraction or reception of heat. This he does by covering himself with substances which are bad conductors of caloric, and retain an atmosphere next to the surface, which is warmed by the caloric of the body. He is compelled, also, in the colder seasons, to have recourse to artificial temperature.

It will be obvious, from what has already been said, that the greater the degree of activity of any organ or set of organs, the greater will be the heat developed; and, in this way, muscular exertion and digestion influence its production.

By an attention to all these points, and by his acquaintance with the physical laws relative to the developement and propagation of caloric, man is enabled to live amongst the arctic snows, and to exist in climates, where the temperature is frequently, for a length of time, upwards of 150° lower than that of his own body. The

contrivances, adopted in the polar voyages, under the direction of Captain Parry and others, are monuments of ingenuity, directed to obviate one of the greatest obstacles to prolonged existence in those inhospitable regions, for which man is naturally incapacitated, and for which he attains the capability solely by the exercise of that superior intellect, with which he has been vested by the author of his being.

In periods of intense cold, the extreme parts of the body do not possess the necessary degree of vitality to resist congelation, unless they are carefully protected. In the disastrous expeditions of Napoleon to Russia, the loss of the nose and ears was a common casualty; and, in arctic voyages, frost-bites occur in spite of every care.

When the temperature of the whole body sinks to about 78° or 79°, death takes place, preceded by the symptoms of nervous depression, which have been previously depicted.

The counteracting influence, which is exerted, when the body is exposed to a temperature greatly above the ordinary standard of the animal, is as difficult of appreciation as that by which calorification is effected. The probability is, that, in such case, the disengagement of animal heat is suspended; and that the body receives heat from without, by direct, but not by rapid, communication, owing to its being an imperfect conductor of caloric. Through the agency of this extraneous heat, the temperature rises a limited number of degrees; but its elevation is checked by the evaporation, constantly taking place through the cutaneous and pulmonary transpirations. For this last idea, we are indebted to Franklin, and its correctness and truth has been amply confirmed. MM. Berger and De La Roche put into an oven,—heated to from 120° to 140°,—a frog, one of those porous vessels, called *alcarazas*,—which permit the transudation of the fluid, within them, through their sides,—filled with water at the animal heat, and two sponges, imbibed with the same water. The temperature of the frog at the expiration of two hours, was 99°; and the other bodies continued at the same. Having substituted a rabbit for the frog, the result was identical. On the other hand, having placed animals in a warm atmosphere, so saturated with humidity that no evaporation could occur, they received the caloric by communication, and their temperature rose; whilst inert evaporable bodies, put into a dry stove, became but slightly warmed;—much less so, indeed, than the warm-blooded animals in the moist stove.

Hence they concluded, that evaporation is a great refrigerative agent when the body is exposed to excessive heat; a conclusion which is likewise confirmed by the loss in weight, which animals sustain by the experiment.

Dr. Edwards, in his experiments on the influence of physical agents on life, found, that warm-blooded animals have less power of producing heat, after they have been exposed for some time to

an elevated temperature, as in summer,—whilst the opposite effect occurs in winter. He instituted a series of experiments, which consisted in exposing birds to the influence of a freezing mixture, first in February, and afterwards in July and August, and observing in what degree they were cooled by remaining in this situation for equal lengths of time; the result of which was, that the same kind of animal was cooled six or eight times as much in the summer as in the winter months. This principle he presumes to be of great importance in maintaining the regularity of the temperature at the different seasons; even more so than evaporation, the effect of which, in this respect, he thinks, has been greatly exaggerated.

From several experiments on yellow hammers made at different periods in the course of the year, it would result, that the averages of their temperature ranged progressively upwards from the depth of winter to the height of summer, within the limits of five or six degrees of Fahrenheit, and the contrary was observed in the fall of the year. Hence, Dr. Edwards infers, and with every probability, that the temperature of man experiences a similar fluctuation.

When exposed to high atmospheric temperature, the ingenuity of man has to be as much exerted as in the opposite condition. The clothing must be duly regulated according to physical principles,* and perfect quietude be observed, so that undue activity of any of the organs that materially influence the disengagement of animal heat, may be prevented.

It is only within limits, that this refrigeratory action is sufficient. At a certain degree, the transpiration is inadequate, the temperature of the animal rises, and death supervenes.

* See the chapter on Clothing in the author's 'Elements on Hygiène,' p. 388.

SECRETION.

We have yet to describe an important and multiple function, which takes place in the very tissue of our organs—in the capillary system—and which separates from the blood the various humours of the body. This is the function of *secretion*,—a term which has been applied both to the operation and the product. Thus, the liver is said to separate the bile from the blood by an action of secretion, and the bile is said to be a secretion.

The organs that execute the various secretory operations differ greatly, in the aggregate, from each other. They have, however, been grouped by anatomists in three classes, each of which will require a general notice.

Anatomy of the Secretory Apparatus.

The secretory organs have been divided into *exhalant*, *follicular*, and *glandular*.

The remarks made respecting the *exhalant vessels*, under the head of nutrition, will render it unnecessary to allude, in this place, to any of the apocryphal descriptions of them, especially as their very existence is supposititious. Many, indeed, imagine them to be nothing more than the minute radicles of ordinary arteries.

The *follicle* or *crypt* has the form of an ampulla or vesicle, and is situated in the substance of the skin and mucous membranes; secreting a fluid for the purpose of lubricating those parts. In the exhalant vessel, the secreted fluid passes immediately from the blood-vessel, without being received into any excretory duct; and, in the follicle, there is essentially no duct specially destined for the excretion of the humour.

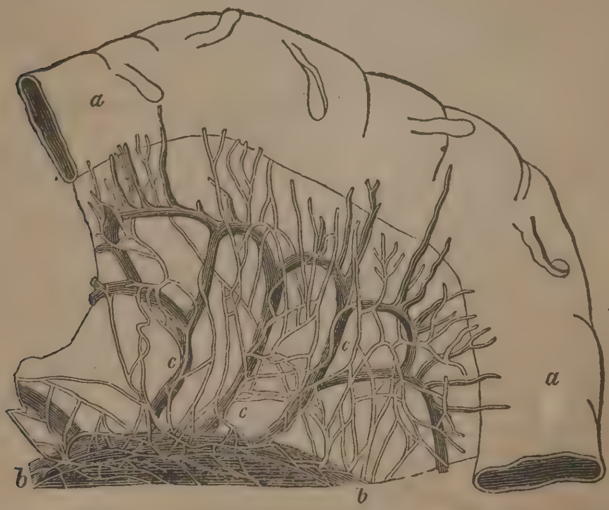
The follicle is membranous and vascular, having an internal cavity in which the secretion is accomplished; and the product is poured upon the surface beneath which it is situated, either by a central aperture, or by a very short duct—if duct it can be called—termed a *lacuna*.

The *gland* is of a more complex structure than the last. It consists of an artery which conveys blood to it; of an intermediate body,—the *gland*, properly so called,—and of an excretory duct to carry off the secreted fluid, and to pour it on the surface of the skin or mucous membranes. The blood-vessel that conveys to the gland the material from which the secretion has to be operated, enters the organ, at times, by various branches; at others, by a

single trunk, and ramifies in the tissue of the gland; communicating at its extremities with the origins of the veins and of the excretory ducts. These ducts arise by fine radicles at the part where the arterial ramifications terminate; and they unite to form larger and less numerous canals, until they terminate in one large duct, as in the pancreas; or in several, as in the lachrymal gland; the duct generally leaving the gland at the part where the blood-vessel enters. Of this we have a good exemplification in the kidney, (see Fig. 139.)

Besides these vessels, veins exist, which communicate with the vessels that convey blood to the gland, both for the formation of the humour and the nutrition of the organ, and return the residuary blood to the heart. Lymphatic vessels are likewise there; and nerves,—which proceed from the ganglionic system,—form a net-work around the secreting arteries, as in Fig. 136, accompany them into the interior of the organ, and terminate, like them, invisibly.

Fig. 136.



a a. A portion of the intestine.—*b b*. Part of the aorta.—*c c*. Nerves following the branches of the aorta, to supply the intestine.

Bordeu was of opinion, that the glands, judging from the parotid, are largely supplied with nerves. The nerves, however, do not all belong to it, some merely crossing it in their course to other parts. Bichat, from the small number sent to the liver, was induced to draw opposite conclusions to those of Bordeu.

These may be looked upon as the great components of the glandu-

lar structure. They are bound together by cellular membrane, and have generally an outer envelope.

The intimate texture of these organs has been a topic of much speculation. It is generally considered, that the final ramifications of the arterial vessels, with the radicles of the veins and excretory ducts, and the final ramifications of the lymphatic vessels and nerves, form so many small lobules, composed of minute, granular masses. Such, indeed, is the appearance the texture presents, when examined by the naked eye. Each lobule is conceived to contain a final ramification of the vessel or vessels that convey blood to the organ, a nerve, a vein, a lymphatic, and an excretory duct,—with cellular tissue binding them together. When the organ has an external membrane, it usually forms a sheath to the various vessels. The lobated structure is not equally apparent in all the glands. It is well seen in the pancreas, and in the salivary and lachrymal.

The precise mode in which the blood-vessel, from the blood of which the secretion is effected, communicates with the excretory duct, does not admit of detection. Some have supposed, that between the termination of the blood-vessel and the commencement of the duct, a secretory vessel, specially charged with the function, exists, which conveys the secreted humour into the excretory duct. Of this, however, we have no evidence; and the existence of any, except the minute capillary vessel, appears needless.

Malpighi maintained, that such glands as the liver are composed of very minute bodies, called *acini*, from their resemblance to the stones of grapes; that these acini are hollow internally, and are covered externally by a net-work of blood-vessels; and that these minute blood-vessels pour into the cavities of the acini the secreted fluid, from which it is subsequently taken up by the excretory ducts. Ruysch, however, satisfied himself, that the acini of Malpighi are merely convoluted vessels, and that they are continuous with the excretory ducts. In Malpighi's view, the secretory organ is a mere collection of follicles; in Ruysch's, simply an exhalant membrane variously convoluted. The latter is the view almost universally embraced by the anatomist and physiologist. "The chief, if not the only difference," says Sir Charles Bell, "between the secreting structure of glands and that of simple surfaces, appears to consist in the different number and the different arrangement of their capillary vessels. The actual secreting organ is in both cases the same,—capillary blood-vessel; and it is uncertain whether either its peculiar arrangement, or greater extent in glandular texture, be productive of any other effect than that of furnishing the largest quantity of blood-vessels within the smallest space. Thus convoluted and packed up, secreting organ may be procured to any amount that may be required, without the inconveniences of bulk and weight."

It is manifest, then, that the three classes of secretory organs, however different they may appear to be, are essentially varieties of the same structure; that the capillary vessel is the important agent of the secretion; that the simplest form of the secretory apparatus is this simple capillary vessel; and that the follicles and glands are structures of a more complex organization.

Physiology of Secretion.

The uncertainty, which rests upon the intimate structure of secreting organs, and upon the mode in which the different blood-vessels communicate with the commencement of the excretory duct, envelopes the function, executed by those parts, in obscurity. We see the pancreatic artery pass to the pancreas, ramify in its tissue, become capillary, and escape detection; and we see other vessels becoming larger and larger, and emptying themselves into vessels of greater magnitude, until, ultimately, all the secreted humour is contained in one large duct, which passes onwards and discharges its fluid into the small intestine. Yet if we follow the pancreatic artery as far as the eye can carry us, even when aided by glasses of considerable magnifying power, or if we trace back the pancreatic duct as far as practicable, we find, in the former vessel, always arterial blood, and, in the latter, always pancreatic juice. It must, consequently, be between the part at which the artery ceases to be visible, and at which the pancreatic duct becomes so, that secretion is effected; and we cut the knot by asserting, that it occurs in the very tissue, parenchyma, or in the capillary system of the secretory organ.

Conjecture, in the absence of positive knowledge, has been busy, at all times, in attempting the explanation of the mysterious agency by which we find such various humours separated from the same fluid; and, according as chymical, or mechanical, or vital doctrines have prevailed in physiology, the function has been referred to one or other of those agencies.

The general belief, amongst the physiologists of the sixteenth and seventeenth centuries, was, that each gland possesses a peculiar kind of fermentation, which assimilates to its own nature the blood passing through it. The notion of fermentation was, indeed, applied to most of the vital phenomena. It is now totally abandoned, owing to its being purely imaginary, and inconsistent with all our ideas of the vital operations. When this notion passed away, and the fashion of accounting for physiological phenomena on mechanical principles usurped its place, the opinion prevailed, that the secretions are effected through the glands as through filters. To admit of this mechanical result, it was maintained, that all the secreted fluids exist ready formed in the blood, and that, when they respectively arrive at the different secretory organs, they pass through, and are received by the excretory ducts.

Descartes and Leibnitz were warm supporters of this mechanical doctrine, although their views differed materially with regard to the precise nature of the operation. Descartes supposed, that the particles of the various humours are of different shapes, and that the pores of the glands have respectively a corresponding figure; so that each gland permits those particles only to pass through it which have the shape of its pores. Leibnitz, on the other hand, likened the glands to filters, which had their pores saturated with their own peculiar substance, so that they admitted this substance to pass through them, and excluded all others,—as paper, saturated with oil, will prevent the filtration of water.

The mechanical doctrine of secretion was taught by Malpighi and by Boerhaave, and it continued to prevail even till the time of Haller. All the secretions were conceived to be ready formed in the blood, and the glands were looked upon as sieves or strainers to convey off the appropriate fluids or humours. In this view of the subject, all secretion was a transudation through the coats of the vessels,—particles of various sizes passing through pores adapted to them.

The mechanical doctrine of transudation, in this shape, is founded upon supposititious data; and the whole facts and arguments are so manifestly defective, that no refutation is necessary. It is now, indeed, wholly abandoned. MM. Magendie and Fodéra have, however, revived the mechanical doctrine of late years, but under an essentially different form; and one applicable especially to the exhalations.

The former gentleman, believing that many of the exhalations exist ready formed in the blood, thinks, that the character of the exhaled fluid is dependent upon the physical arrangement of the small vessels, and his views repose upon the following experiments.

If, in the dead body, we inject warm water into an artery passing to a serous membrane, as soon as the current is established from the artery to the vein, a multitude of minute drops may be observed oozing through the membrane, which speedily evaporate.

If, again, a solution of gelatine, coloured with vermilion, be injected into all the vessels, it will often happen, that the gelatine is deposited around the cerebral convolutions, and in the anfractuosities, without the colouring matter escaping from the vessels, whilst the latter is spread over the external and internal surface of the choroid. If, again, linseed oil, also coloured with vermilion, forms the matter of the injection, the oil, devoid of colouring matter, is deposited in the articulations, that are furnished with large synovial capsules, whilst no transudation takes place at the surface of the brain, or in the interior of the eye.

Magendie asks, if these are not instances of true secretion taking place *post mortem*, and evidently dependent upon the physical arrangement of the small vessels; and whether it is not extremely

probable, that the same arrangement must, in part at least, preside over exhalation during life?

Fodéra, to whose experiments on the imbibition of tissues we had occasion to allude under the head of absorption, embraces the views of Magendie. If the vessels of a dead body, he remarks, be injected, the substance of the injection is seen oozing through the vessels; and if an artery and a vein be exposed in a living animal, a similar oozing through the parietes is observable. This is more manifest if the trunk, whence the artery originates, be tied; the fluid being occasionally bloody. If the jugular veins be tied, not only œdema occurs in the parts above the ligatures, but there is an increase of the salivary secretion.

It is not necessary to adduce the various experiments of Fodéra, relating to this topic, or those of Lawrence, Coates and Harlan, or of Dutrochet, Faust, Mitchell and others. They are of precisely the same character as those that we have previously described regarding the imbibition of tissues; and transudation is only imbibition or soaking from within to without; Magendie and Fodéra, indeed, conclude, that one primary physical cause of exhalation is the same as that of absorption, namely, imbibition.

Another physical cause, adduced by Magendie, is the pressure experienced by the blood in the circulatory system, which, he conceives, contributes powerfully to cause the more aqueous part to pass through the coats of the vessels. If water be forcibly injected, by means of a syringe, into an artery, all the surfaces, to which the vessel is distributed, as well as the larger branches and the trunk itself, exhibit the injected fluid oozing in greater abundance, according to the force exerted in the injection.

He farther remarks, if water be injected into the veins of an animal, in sufficient quantity to double or treble the natural amount of blood, a considerable distention of the circulatory organs is produced; and, consequently, the pressure, experienced by the circulating fluid, is largely augmented. If any serous membrane be now examined,—as the peritoneum,—a serous fluid is observed issuing rapidly from its surface, which accumulates in the cavity, and produces a true dropsy under the eyes of the experimenter, and, occasionally, the colouring part of the blood transudes at the surface of certain organs, as the liver, spleen, &c.

Hamberger, again, broached the untenable physical hypothesis, that each secreted humour is deposited in its proper secretory organ, by virtue of its specific gravity.

It is obvious, that all these speculations proceed upon the belief, that the exhalations exist ready formed in the blood; and that, consequently, the act of secretion, so far as concerns them, is one of separation or of secerning,—not of fresh formation.

That this is the case with the more aqueous secretions is probable, and not impossible with regard to the rest. Organic chymistry is, however, subject to more difficulties in the way of analysis than

inorganic; and it can be readily understood, that, in a fluid so heterogeneous as the blood, the discovery of any distinct humour may be impracticable. Of course, the elements of every fluid, as well as solid, must be contained in it; and we have already seen, that not merely the inorganic elements, but the organic or compounds of organization, have been detected by the labours of Chevreul and others.

There are, indeed, some singular facts connected with this subject. MM. Prévost and Dumas having removed the kidneys in cats and dogs, and afterwards analyzed the blood, found urea in it —the characteristic element of urine. This principle was contained in greater quantity, the longer the period that had elapsed after the operation; whilst it cannot be detected in the blood, where the kidneys exist. The experiment was soon afterwards repeated by Vauquelin and Ségalas with the same results. The latter introduced urea into the veins of an animal, whose kidneys were untouched; he was unable to detect the principle in the blood; but the urinary secretion was largely augmented after the injection. Whence he concludes that urea is an excellent diuretic. Very recently, MM. Gmelin and Tiedemann, in association with M. Mitscherlich, have arrived, experimentally, at the same conclusions as MM. Prévost and Dumas. The existence of urea in the fluid ejected from the stomach of the animal, was rendered probable, but there were no traces of it in the fæces or the bile. The animal died the day after the extirpation of the second kidney. They were totally unable to detect either urea, or sugar of milk in the healthy blood of the cow.

Adelon asserts, that, since their experiments on urea, MM. Prévost and Dumas are said to have found the principles of other secreted humours in the blood, after the secretory organs of the respective humours had been removed on the living animal; and it has been affirmed, that, after having extirpated the testicles of a frog, artificial fecundation was effected with the blood of the animal; and that after the removal of the mammæ in animals, sugar of milk has been detected in the blood. These circumstances, if correct, would favour the idea, that the secretions may be formed in the blood, and may simply require the intervention of a secreting organ to separate them; but the mode in which such separation is effected, is entirely inexplicable under the doctrine of simple mechanical filtration or transudation. It is unlike any physical process, which can be imagined.

The doctrines of filtration and transudation can apply only to those exhalations, in which the humour has undergone no apparent change; and it is obviously impossible to specify these, in the imperfect state of our means of analysis. In the ordinary aqueous secretions, simple transudation may embrace the whole process; and, therefore, it is unnecessary to have recourse to any other explanation; especially after the experiments instituted by Magendie, sup-

ported by the pathological observations of Bouillaud, of Paris, Dr. D. Davis, of the London University, Ribes, Velpeau, and others. Bouillaud found, that partial œdema of the legs was constantly accompanied by more or less complete obliteration of the veins of the infiltrated part,—the vessels being obstructed by fibrinous coagula, or compressed by circumjacent tumours; and he suggests, that ascites or dropsy of the lower belly is frequently occasioned by obstruction of the portal circulation in the liver. In this way, we can account for the numerous cases in which we find a union of hydropic and hepatic affections in the same individual.

The same pathological doctrine, founded on direct observation, has been extended to phlegmatia dolens, or swelled leg; an affection occurring in the puerperal state, and which has been found connected with obstruction in the great veins that convey the blood back from the lower extremity.

The generality of physiologists have regarded the more complex secretions—the follicular and the glandular—as the results of chymical operations; and under the view, that they do not exist ready formed in the blood, and that the elements alone are contained in that fluid, it is impossible not to admit that chymical agency must be exerted.

In support of the chymical hypothesis, which has appeared under various forms,—some, as Keil, presuming that the secretions are formed in the blood, before they arrive at the place appointed for secretion; others, that the change is effected in the glands themselves,—the fact of the formation of a number of substances from a very few elements, provided these be united in different proportions, has been invoked. For example, take the elementary bodies, oxygen and azote. These, in one proportion, compose atmospheric air; in another, nitrous oxide; in another, nitric oxide; in a fourth, hyponitrous acid; in a fifth, nitrous acid, and in a sixth, nitric acid; substances which differ as much as the various secretions differ from each other and from the blood. Many of the compounds of organization likewise exhibit by their elementary composition, that but a slight change is necessary, in order that they may be converted into each other. Dr. Prout has exhibited this close alliance between three substances—urea, lithic acid and sugar—and has shown how they may be converted into each other, by the addition or subtraction of single elements of their constituents. Urea is composed of two atoms of hydrogen, and one of carbon, oxygen and azote respectively; by removing one of the atoms of hydrogen and the atom of nitrogen, it is converted into sugar; by adding to it an additional atom of carbon, into lithic acid.

Bostock,—who is disposed to push the application of chymistry to the explanation of the functions as far as possible,—to aid us in conceiving how a variety of substances may be produced from a single compound, by the intervention of physical causes alone, supposes the case of a quantity of the materials adapted for the vinous

fermentation being allowed to flow from a reservoir, through tubes of various diameters, and with various degrees of velocity. "If we were to draw off portions of this fluid in different parts of its course or from tubes, which differed in their capacity, we should, in the first instance, obtain a portion of unfermented syrup; in the next, we should have a fluid in a state of incipient fermentation; in a third, the complete vinous liquor; while in a fourth, we might have acetous acid." Any explanation, however, founded upon this loose analogy, is manifestly too physical: this Bostock admits, for he subsequently remarks, that "if we adopt the chymical theory of secretion, we must conceive of it as originating in the vital action of the vessels, which enables them to transmit the blood, or certain parts of it, to the various organs or structures of the body, where it is subjected to the action of those reagents, which are necessary to the production of these changes."

The admission of such vital agency, in some shape, seems to be indispensable. Attempts have, indeed, been made to establish secretion as a nervous action; and numerous arguments and experiments have been brought forward in support of the position.

That many of the secretions are affected by the condition of the mind, is known to all. The act of crying, in evidence of joy or sorrow; the augmented action of the salivary glands at the sight of pleasant food; the increased secretion of the kidney during fear or anxiety, and the experimental confirmation, by Mr. Hunter, of the truth of the common assertion—that the she-ass gives milk no longer than the impression of the foal is on her mind; the skin of her foal, thrown over the back of another, and frequently brought near her, being sufficient to renew the secretion,—sufficiently indicate, that the organs of secretion can be influenced through the nervous system in the same manner as the functions of nutrition and calorification.

The discovery of galvanism naturally suggested it as an important agent in the process,—or rather suggested, that the nervous fluid strongly resembles it. This conjecture seems to have been first hazarded by Berzelius, and by Sir Everard Home; and, about the same time, an experiment was made by Dr. Wollaston, which he conceived to throw light upon the process. He took a glass tube, two inches high and three-quarters of an inch in diameter; and closed it at one extremity with a piece of bladder. He then poured into the tube, a little water, containing $\frac{1}{240}$th of its weight of muriate of soda, moistened the bladder on the outside, and placed it upon a piece of silver. On curving a zinc wire so that one of its extremities touched the piece of metal, and the other dipped into the liquid to the depth of an inch, the outer surface of the bladder immediately indicated the presence of pure soda; so that, under this feeble electric influence, the muriate of soda was decomposed, and the soda, separated from the acid, passed through the bladder.

M. Fodéra performed a similar experiment, and found, that whilst ordinary transudation frequently required an hour before it was evidenced, it was instantaneously exhibited under the galvanic influence. On putting a solution of prussiate of potassa into the bladder of a rabbit; forming a communication with the solution by means of a copper wire; and placing, on the outside, a cloth, soaked in a solution of sulphate of iron, to which an iron wire was attached; he found, by bringing these wires into communication with the galvanic pile, that the bladder or the cloth was suddenly coloured blue, according as the galvanic current, set from without to within, or from within to without;—that is, according as the iron wire was made to communicate with the positive pole, and the copper wire with the negative, or conversely.

The disposition, with some of the chymical physiologists of the day is to resolve secretion into a mere play of electric affinities. Thus, M. Donné affirms, that from the whole cutaneous surface is secreted an acid humour, whilst the digestive tube, except in the stomach, secretes an alkaline mucus; and hence, he infers, that the external *acid*, and the internal *alkaline*, membranes of the human body represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer. On placing one of the conductors of the instrument in contact with the mucous membrane of the mouth, and the other in contact with the skin, the magnetic needle, he affirms, deviated fifteen, twenty, and even thirty degrees, according to its sensibility; and its direction indicated, that the mucous or alkaline membrane took negative, and the cutaneous membrane, positive electricity. He further asserts, that between the *acid* stomach, and the *alkaline* liver, extremely powerful electrical currents are formed. These experiments do not, however, aid us materially in our solution of the phenomena of secretion. They exhibit merely electric phenomena dependent upon difference of chymical composition. This is, indeed, corroborated by the experiments of M. Donné himself on the secretions of vegetables. He observed electrical phenomena of the same kind in them, but, he says, electric currents in vegetables are not produced by the acid or alkaline conditions of the parts as in animals, the juice of fruits being always more or less acid. Experiments of M. Biot, however, show, that the juices, which arrive by the pedicle, are modified in some part of the fruit, and M. Donné thinks it is perhaps to this difference in the chymical composition of the juices of the two extremities, that the electrical phenomena are to be attributed.

The effects of the section of the pneumogastric nerves on the functions of digestion and respiration, have been given elsewhere, at some length. It was there stated, that when digestion was suspended by their division, Dr. Wilson Philip was led to ascribe it to the secretion of the gastric juice having been arrested; an opinion, which Sir B. Brodie had been induced to form previously, from the results of experiments, which showed, that the secretion of urine is

suspended by the removal or destruction of the brain; and that when an animal is destroyed by arsenic, after the division of the pneumogastric nerves, all the usual symptoms are produced, except the peculiar secretion from the stomach. Sir B. Brodie did not draw the conclusion, that the nervous influence is absolutely necessary to secretion, but that it is a step in the process, and the experiments of Magendie, on the effect of the division of the nerve of the fifth pair on the nutritive secretion of the cornea confirm the position. We have, indeed, numerous evidences, that the nervous system cannot be indispensable to secretion. In all animals, this power must exist, yet there are some in which no nervous system is apparent. Bostock has given references, in a note, to many cases of monstrous or deformed fœtuses, born with many of their organs fully developed, yet where there was no nervous system. It may be said, however, that, in all these cases, an organic nervous system must have existed, but setting aside the cases of animals, we have the most indisputable testimony of the existence of secretion in the vegetable in which there is no nervous system, or, at the most, a rudimental one; yet the function is accomplished as perfectly, although not in as multiple a manner, as in man.

It is manifest, therefore, that this is one of the vital actions occurring in the very tissue of organs, of which we have no more knowledge than we have of the capillary actions in general. All that we know is, that in particular organs various humours are secreted from the blood, some of which can be detected in that fluid, others not, but we are ignorant of the precise agency, by which this mysterious process is effected.

In cases of vicarious secretion, we have the singular phenomenon of organs assuming an action for which they were not destined. If the secretion from the kidney, for example, be arrested, urine is occasionally found in the ventricles of the brain, and, at other times, a urinous fluid has been discharged by vomiting or by cutaneous transpiration; the capillaries of these parts must, consequently, have assumed the functions of the kidney, and to this they must be excited by the presence of urea, or of the elements of the urinary secretion in the blood —a fact, which exhibits the important influence, which the condition of the blood must exert on the secretions, and, indeed, on nutrition in general. It is thus that many of our remedial agents,—as alkalies, the preparations of iodine, &c. produce their effects. They first enter the mass of blood, and, by circulating in the capillary system, induce a modification of its functions. There are other cases, again, in which the condition of the blood being natural, the vessels of nutrition may take on morbid action. Of this we have examples in the ossification of organs, which, in the healthy condition, have no osseous constituent; in the deposition of fat in cases of diseased ovaria; and in the altered secretions produced by any source of irritation in a secreting organ.

In describing the physiology of the different secretions, one of three arrangements has usually been adopted; either according to the nature of the secreting organ, the functions of the secreted fluid, or its chymical character.

The first of these has been followed by Bichat and by Magendie, who have adopted the division into *exhaled*, *follicular* and *glandular* secretions. It is the arrangement followed by Lepelletier except that he substitutes the term *perspiratory* for *exhaled*. According to the second, embraced by Boyer, Sabatier, and Adelon, they are divided into *recrementitial* secretions or such as are taken up by internal absorption and re-enter the circulation, and into *excrementitial*, or such as are evacuated from the body and constitute the excretions. Some physiologists add a third division—the *recremento-excrementitial*,—in which a part of the humour is absorbed and the remainder is ejected. Lastly, the division, according to chymical character has been followed, with more or less modification, by Plenck, Richerand, Blumenbach, Young, and Bostock: the last of whom, the most recent writer, has eight classes:—the *aqueous*, *albuminous*, *mucous*, *gelatinous*, *fibrinous*, *oleaginous*, *resinous*, and *saline*. To all of these classifications, cogent objections might be made. The one we shall follow is the anatomical, not because it is the most perfect, but because it is the course, that has been usually adopted throughout this work.*

Sect. I.—Of the Exhalations.

All the exhalations take place in the areolæ or internal cavities of the body, or from the skin and mucous membranes:—hence their division into *internal* and *external*. The former are *recrementitial* the latter *recremento-excrementitial*. To the class of *internal exhalations* belong; 1. The serous exhalation. 2. The serous exhalation of the cellular membrane. 3. The adipous exhalation of the cellular membrane. 4. The exhalation of the marrow. 5. The synovial exhalation. 6. The exhalation of the colouring matter of the skin, and of other parts; and 7. The areolar exhalation. To the class of *external exhalations* belong; 1. That of the skin, or cutaneous transpiration. 2. The exhalation of the mucous membranes.

1. *The Serous Exhalation.*

This is the fluid secreted by the serous membranes that line the various cavities of the body;—as the pleura, pericardium, peritoneum, arachnoid coat of the brain, and tunica vaginalis testis.

From these membranes a fluid is exhaled, which is of an albuminous character, considerably resembling the serum of the blood except in containing less albumen. M. Donné says it is always alkaline in the healthy state.

In the healthy condition, this fluid never accumulates in the ca-

vities; the absorbents taking it up in proportion as it is deposited; but if, from any cause, the exhalants should pour out a larger quantity than usual, whilst the absorbents are not proportionably excited, accumulation may take place; or the same effect may ensue if the exhalants pour out no more than their usual quantity, whilst the absorbents do not possess their due activity. Under either circumstance, we have accumulation or dropsy.

The exhaled fluid probably transudes through the parietes of the arteries, and re-enters the circulation by imbibition through the coats of the veins. If we kill an animal and open it immediately afterwards, this exhalation appears in the form of a halitus or vapour, and the fluid is seen lubricating the free surface of the membrane.

This, indeed, appears to be its principal office; by which it favours the motion of the organs upon each other.

The serous exhalations probably differ somewhat in each cavity, or according to the precise structure of the membrane. The difference between the chymical character of the fluid of the dropsy of different cavities would lead to this belief. As a general rule, according to Dr. Bostock, the fluid from the cavity of the abdomen contains the greatest proportion of albumen, and that from the brain the least; but many exceptions occur to this.

2. *Serous Exhalation of the Cellular Membrane.*

The cellular membrane, wherever existing, is kept moist by a serous fluid, analogous to that exhaled from serous membranes, and which appears to have the same uses,—that of facilitating the motion of the lamellæ or plates on each other, and consequently of the organs, between which the cellular tissue is placed.

When this secretion collects, from the causes mentioned in the last section, the disease, called *œdema* or *anasarca*, is induced.

3. *Adipous Exhalation of the Cellular Membrane.*

Considerable diversity of opinion has prevailed regarding the precise organ of the secretion of *fat*. Haller supposed that the substance exists ready formed in the blood, and that it simply transudes through the pores of the arteries; and Chevreul and others have given some countenance to this opinion, by the circumstance of their having met with a fatty matter in that fluid.

Anatomists have, likewise, been divided upon the subject of the precise tissue into which the fat is deposited; some believing it to be the ordinary cellular tissue, into which it is dropped by the agency of appropriate vessels; others, as Malpighi and William Hunter, believing in the existence of peculiar adipous tissue, consisting, according to Béclard, of small bursæ or membranous vesicles, which inclose the fat, and are found situated in the areolæ of the cellular tissue. These vesicles are said to vary greatly in size: generally,

they are round and globular; and, in certain subjects, receive vessels, that are very apparent. They form so many small sacs without apertures, in the interior of which are filaments arranged like septa. In fatty subjects, these adipous vesicles are very perceptible, being attached to the cellular tissue and neighbouring parts by a vascular pedicle.

M. Raspail affirms, that there is the most striking analogy between the nature of the adipous granules and that of the amylaceous grains. As in the case of fecula, each adipous granule is composed of at least one integument, and an inclosed substance, both of which are as slightly azoted as fecula; and both fecula and fat are equally inservient to the nutrition of the organs of developement: whenever there is excess of life and activity, the fat is seen to disappear, and whenever there is rest, it accumulates in its reservoirs. If a portion of fat be examined, it is found to consist of an outer vesicle with strong membranous parietes, containing small adipous masses readily separable from each other, each invested with a similar, but slighter, vesicular membrane; and these, again, contain others still more minute, until ultimately we come to the vesicles that invest the adipous granules themselves. Each of these masses adheres, at some point of its surface, to the inner surface of the vesicle that incloses it by a hilum in the same manner as the grain of fecula. All the vesicles, but especially the outermost and strongest, have a reddish vascular net-work on their surface, the vessels of which augment in size, as they approach the part where the vesicle is adherent, and there they open into one of the vessels of the larger vesicle that incloses them.

The arrangement of this tissue, as well as the quantity of fat, varies in different parts of the body. It is always found in the orbit, on the sole of the foot, and at the pulps of the fingers and toes. The subcutaneous cellular tissue, and that covering the heart, kidneys, &c. also generally contain it: but it is never met with in the eyelids, scrotum, or within the cranium.

Fat is exhaled by the secretory vessels in a fluid state; but after it is deposited, it becomes more or less solid. According to the researches of Chevreul and Braconnot, human fat is almost always of a yellow colour; inodorous, and composed of two portions;—the one fluid, and the other concrete, which are themselves composed, but in different proportions, of two new immediate principles, to which that chymist gave the names *elaine* and *stearine* respectively.

It is probable, that chymical analysis would exhibit the fat to vary in different parts of the body, as its sensible properties are manifestly different. Sir Everard Home, on loose analogies and inconclusive arguments, has advanced the opinion, that it is more than probable, that fat is formed in the lower portion of the intestines, and from thence is carried, through the medium of the circulating blood, to be deposited in almost every part of the body. "When there is a great demand for it, as in youth, for carrying on growth, it is laid immediately under the skin, or in the neighbour-

hood of the abdomen. When not likely to be wanted, as in old age, it is deposited in the interstices of muscular fibres, to make up in bulk for the wasting of these organs."

M. de Blainville is of opinion, that fat is derived from venous blood, and that it is exhaled through the coats of the vessels. This opinion he founds on the mode in which the fat is distributed in the omenta along the course of the veins; and he affirms, that he has seen it flow out of the jugular vein in a dead elephant. But this last fact, as Lepelletier has judiciously remarked, proves nothing more than that the fat, taken up, by the absorbents, from the vesicles, in which it had been deposited by the exhalants, had been conveyed into the venous blood with other absorbed matters. It in no wise shows, that the venous blood is the pabulum of the secretion, or that the veins accomplish it.

The uses of the fat are both *general* and *local*. The great general use is, by some physiologists, conceived to be,—to serve as a provision in cases of wasting indisposition; when the digestive function is incapacitated for performing its due office, and emaciation is the consequence. In favour of this view, the rapidity with which fat disappears after slight abstinence has been urged, as well as the facts, connected with the torpidity of animals, which are always found to diminish in weight during this state.

Professor Mangili, of Pavia, procured two marmots from the Alps, on the first of December. The larger weighed 25 Milanese ounces; the smaller only $22\frac{1}{8}$th; on the third of January, the larger had lost $\frac{3}{4}$ths of an ounce, and the smaller $\frac{17}{24}$ths. On the fifth of February, the larger weighed only $22\frac{7}{8}$ths; the smaller 21.

Dr. Monro kept a hedge-hog from the month of November to the month of March following, which lost, in the meanwhile, a considerable portion of its weight. On the 25th of December, it weighed 13 ounces and 3 drachms; on the 6th of February, 11 ounces and 7 drachms; and on the eighth of March, 11 ounces and 3 drachms. The loss was 13 grains daily.

The local uses of the fat are chiefly of a physical character. On the sole of the foot it diminishes the effects of pressure, and its use is the same on the nates: in the orbit, it forms a kind of cushion, on which the eyeball moves with facility; and when in certain limits, it gives that rotundity to the frame, which we are accustomed to regard as symmetry. In another place, it was observed, that fatty substances are bad conductors of caloric; and hence that it may tend to preserve the temperature of the body in cold seasons;—a view, which is favoured by the fact, that many of the arctic animals are largely supplied with fat beneath the common integuments; and it has been affirmed, that fat people generally suffer less than lean from the cold of winter.

It is obviously impracticable to estimate, accurately, the total quantity of fat in the body. It has been supposed, that, in an adult male of moderate size, it forms $\frac{1}{20}$th of the whole weight; but it is

doubtful whether we ought to regard this as even an approximation; the data being so inadequate.

In some cases of polysarcia or obesity, the bulk of the body has been enormous. In the *Philosophical Transactions*, No. 185, the case of a girl is detailed, who weighed 256 pounds, when only four years old. A man of the name of Bright, at Maldon, England, weighed 728 pounds; and the celebrated Daniel Lambert, of Leicester, England, weighed 739 pounds a little before his death, which occurred in the fortieth year of his age. The circumference of his body was three yards and four inches; of his leg one yard and one inch. His coffin was six feet four inches long; four feet four inches wide; and two feet four inches deep. Dr. Elliotson says he saw a female child, but a year old, who weighed sixty pounds. She had begun to grow fat at the end of the third month.

In some of the varieties of the human family we meet with singular adipous deposits. In the Bosjesman female vast masses of fat accumulate on the buttocks, which give them the most extravagant appearance. The projection of the posterior part of the body, in one subject, according to Barrow, measured five inches and a half from a line touching the spine. "This protuberance," he remarks, "consisted of fat, and when the woman walked, had the most ridiculous appearance imaginable, every step being accompanied with a quivering and tremulous motion, as if two masses of jelly were attached behind."

The "Hottentot Venus," who had several projections, measured more than nineteen inches across the haunches; and the projection of the hips exceeded $6\frac{1}{3}$ inches. Dr. Somerville found on dissection, that the size of the buttocks arose from a vast mass of fat, interposed between the integuments and muscles, which equalled four fingers breadth in thickness. It is singular, that, according to the statement of this female, which is corroborated by the testimony of Mr. Barrow, this deposition does not take place till the first pregnancy.

Pallas has described a variety of sheep—the *ovis steatopyga* or "fat-buttocked,"—which is reared in immense flocks by the pastoral tribes of Asia. In it, a large mass of fat covers the nates and occupies the place of the tail. The protuberance is smooth beneath, and resembles a double hemisphere, when viewed behind; the os coccygis or rump-bone being perceptible to the touch in the notch between the two. They consist merely of fat; and when very large, shake in walking like the buttocks of the female Bosjesman. Mr. Lawrence remarks, that there are herds of sheep in Persia, Syria, Palestine and some parts of Africa, in which the tail is not wanting as in the *ovis steatopyga*, but retains its usual length and becomes loaded with fat.

The circumstances, which favour obesity, are absence of activity and of excitement of all kinds; hence, for the purpose of fattening animals in rural economy, they are kept in entire darkness,—to deprive them of the stimulus of light, and to favour sleep and mus-

cular inactivity. Castration—by abolishing one kind of excitability—and the time of life at which the generative functions cease to be exerted, especially in the female, are favourable to the same result.

4. *Exhalation of the Marrow.*

A fluid, essentially resembling fat, is found in the cavity of long bones, in the spongy tissue of short bones, and in the areolæ of bones of every kind. This is the *marrow.* The secretory organ is the very delicate membrane, which is perceptible in the interior of the long bones, lining the medullary cavity, and sending prolongations into the compact substance, and others internally, which form septa and spaces for the reception of the marrow. The cells, thus formed, are distinct from each other. From the observations of Howship, it would seem probable, that the oil of bones is deposited in longitudinal canals, that pass through the solid substance of the bone, and through which its vessels are transmitted. This *oil of bones* is the *marrow* of the compact structure, the latter term being generally restricted to this secretion when contained in the cavities of long bones; that which exists in the spongy substance being termed, by some writers, the *medullary juice.*

The *medullary membrane*, called also the *internal periosteum* consists chiefly of blood-vessels ramifying on an extremely delicate cellular tissue, in which nerves may likewise be traced.

Berzelius examined marrow obtained from the thigh-bone of an ox, and found it to consist of the following constituents:—pure adipous matter, 96; skins and blood-vessels, 1; albumen, gelatine, extractive, peculiar matter, and water, 3.

The marrow is one of the corporeal components, of whose use we can scarcely offer a plausible conjecture. It has been supposed to render the bones less brittle; but this is not correct, as those of the fœtus, which contain little or no marrow, are less brittle than those of the adult; whilst the bones of old persons, in which the medullary cavity is extremely large, are more brittle than those of the adult. It is possible, that it may be placed in the cavities of the bones,—which would otherwise be so many vacant spaces,—to serve the general purposes of the fat, when it is required by the system.

The other hypotheses, that have been entertained on the subject, are not deserving of notice.

5. *Synovial Exhalation.*

Within the articular capsules, and the bursæ mucosæ,—which have been described under the head of muscular motion,—a fluid is secreted, which is spread over the articular surfaces of the bones, and facilitates their movements.

Havers considered this fluid to be secreted by *synovial glands*,—for such he conceived the reddish cellular masses to be, that are

found in certain articulations. Haller strangely regarded the synovia as the marrow, which had transuded through the spongy extremities of the bones; but, since the time of Bichat, every anatomist and physiologist has ascribed it to the exhalant action of the synovial membrane, which strongly resembles the serous membranes in form, structure and functions, and whose folds constitute the projections, which Havers mistook for glands.

This membrane exists in all the movable articulations, and in the channels and sheaths in which the tendons play. The generality of anatomists regard the articular capsules as shut sacs; the membrane being reflected over the incrusting cartilages. Magendie, however, affirms, that he has several times satisfied himself, that the membranes do not pass beyond the circumference of the cartilages.

From the inner surface of these membranes, the synovia is exhaled, precisely in the same manner as in other serous cavities.

Margueron analyzed the synovia, obtained from the posterior extremity of the ox, and found it to consist of fibrous matter, 11.86; albumen, 4.52; muriate of soda, 1.75; soda, 0.71: phosphate of lime, 0.70; and water, 80.46. M. Donné says it is always alkaline in health; but in certain diseases it sometimes becomes acid.

6. *Exhalation of the Colouring Matter of the Skin and of other parts.*

The nature of the exhalation, which constitutes the colouring matter of the rete mucosum, has already engaged our attention, when treating of the skin, under the *sense of touch*. It is presumed to be exhaled by the vessels of the skin, and to be deposited beneath the cuticle, so as to communicate the colours that characterize the different races. Such are regarded as the secretory organs by most anatomists and physiologists; but Gaultier, whose researches into the intimate constitution of the skin have gained him much celebrity, is of opinion, that it is furnished by the bulbs of the hair; and he assigns, as reasons for this belief, that the negro, in whom it is abundant, has short hair; that the female, whose hair is more beautiful and abundant than that of the male, has the fairest skin; and that when he applied blisters to the skin of the negro, he saw the colouring matter oozing from the bulbs of the hair, and deposited at the surface of the rete mucosum.

The composition of this pigment cannot be determined with precision, owing to its quantity being too small to admit of examination. Chlorine deprives it of its black hue, and renders it yellow. A negro, by keeping his foot for some time in water, impregnated with this gas, deprived it of its colour and rendered it nearly white; but, in a few days, the black colour returned with its former intensity. This experiment was made with similar results on the fingers of a negro.

Blumenbach, as is noticed elsewhere, thought, that the mucous pigment was formed chiefly of carbon; and the notion has received favour with many.

The uses of this pigment—as well as of that which lines the choroid coat of the eye, the posterior surface of the iris, and of the ciliary processes are detailed in another place.

7. *Areolar Exhalation.*

Under this term, Adelon has included different recrementitial secretions effected within the organs of sense, or in parenchymatous structures,—as the aqueous, crystalline, and vitreous humours of the eye, and the liquor of Cotugno, all of which have already engaged attention; the exhalation of a kind of albuminous, reddish, or whitish lymph into the interior of the lymphatic ganglions, and into the organs, called, by Chaussier, *glandiform ganglions*, and by Béclard, *sanguineous ganglions*;—namely:—the thymus, thyroid, supra-renal capsules, and spleen. We know but little, however, of the fluids, formed in these various parts. They have never been analyzed, and their uses are inappreciable.

By some physiologists, a fluid is supposed to be exhaled from the inner coat of the arterial, venous and lymphatic vessels. Not only, however, are we unaware of the nature of this fluid; its very existence is doubted. Its use is presumed to be, to lubricate the interior of the vessel, and to prevent adhesion between it and the fluid circulating within it.

The following belong to the *external exhalations.*

8. *Cutaneous Exhalation or Transpiration.*

A transparent fluid is constantly exhaled from the skin, which is generally invisible, in consequence of its being converted into vapour as soon as it reaches the surface; but, at other times, owing to augmentation of the secretion, or to the air being loaded with humidity, it is apparent on the surface of the body.

When invisible, it is called the *insensible transpiration* or *perspiration;* when perceptible, *sweat.*

In the state of health, according to Thénard, this fluid reddens litmus paper; yet the taste is rather saline,—resembling that of common salt,—than acid.

Allusion has already been made to the views of M. Donné, who considers, that the external acid, and the internal alkaline membranes of the human body represent the two poles of a pile, the electrical effects of which are appreciable by the galvanometer.

The smell of the perspiration is peculiar, and becomes almost insupportable when concentrated, and especially when subjected to distillation. The fluid is composed, according to Thénard, of much

water, a small quantity of acetic acid, muriate of soda, and perhaps of potassa, a very little earthy phosphate, a trace of oxide of iron, and an inappreciable quantity of animal matter. Berzelius regards it as water, holding in solution the muriates of potassa and soda, lactic acid, lactate of soda, and a little animal matter; and Anselmino, as consisting of a solution of osmazome, chlorurets of soda and lime, acetic acid and an alkaline acetate, salivary matter, sulphates of soda and potassa, and calcareous salts, with mucus, albumen, sebaceous humour, and gelatine in variable proportions.

Raspail strangely regards the sweat as an acid product of the disorganization of the skin.

In a memoir presented to the *Académie Royale des Sciences*, of Paris, MM. Breschet and Roussel de Vauzème have endeavoured to show, that there exists in the skin an apparatus for the secretion of the sweat, consisting of a glandular parenchyma, which secretes the liquid, and of ducts, which pour it out on the surface of the body. These ducts are said to be arranged spirally and to open very obliquely under the scales of the epidermis.

Numerous experiments have been instituted for the purpose of discovering the quantity of transpiration that takes place in a given time. Of these, the earliest were by Sanctorius, for which he is more celebrated than for any other of his labours. For thirty years, this indefatigable experimentalist weighed daily, with the greatest care, his solid and liquid ingesta and egesta, and his own body, with the view of deducing the loss sustained by the cutaneous and pulmonary exhalations. He found, that every twenty-four hours, his body returned sensibly to the same weight, and that he lost the whole of the ingesta;—five-eighths by transpiration, and three-eighths by the ordinary excretions. For eight pounds of ingesta, there were only three pounds of sensible egesta, which consisted of forty-four ounces of urine, and four of fæces.

It is lamentable to reflect, that so much time was occupied in the attainment of such insignificant results. The self-devotion of Sanctorius gave occasion, however, to the institution of numerous experiments of the same kind; as well as to discover the variations in the exhalation, according to age, climate, &c. The results of these have been collected by Haller, but they afford little instruction; especially as they were directed to the transpiration in general, without affording us any data to calculate the proportion exhaled from the lungs to that constantly taking place by the cutaneous surface.

Rye, who dwelt in Cork, lat. 51° 54′, found, in the three winter months—December, January, and February—that the quantity of urine was 3937 ounces; of the perspiration, 4797: in the spring months—March, April, and May—the urine amounted to 3558; the perspiration to 5405: in he summer months—June, July, and August—the urine amounted to 3352; the perspiration to 5719: and in the three autumnal months—September, October, and

November—the quanty of urine was 3369: that of the perspiration 4471.

The daily average estimate, in ounces, was as follows:-

	Urine.	Perspiration.
Winter,	$42\frac{7}{10}$	53
Spring,	40	60
Summer,	37	63
Autumn,	37	50

thus, making the average daily excretion of urine, throughout the year, to be a little more than 39 ounces; and of the transpiration, 56 ounces.

Keil, on the other hand, makes the average daily perspiration, 31 ounces; and that of the urine 38; the weight of the fæces being 5 ounces, and that of the solid and liquid ingesta, 75 ounces. His experiments were made at Northampton, England, lat. 52° 11′.

Bryan Robinson found, as the result of his observations in Ireland, that the ratio of the perspiration to the urine was, in summer, as 5 to 3; in winter as 2 to 3; whilst in April, May, October, November, and December, they were nearly equal. In youth, the ratio of the perspiration to the urine, was as 1340 to 1000; in the aged, as 967 to 1000.

Hartmann, when the solid and liquid ingesta amounted to 80 ounces, found the urine discharged 28 ounces; the fæces 6 or 7 ounces; and the perspirable matter, 45 or 46 ounces. Von Gorter, in Holland, when the ingesta were 91 ounces, found the perspiration to amount to 49 ounces; the urine to 36; and the fæces to 8.

Dodart asserts, that in France, the ratio of the perspiration to the fæces, is as 7 to 1; and to the whole egesta as 15 to 12 or 10. The average perspiration, in the twenty-four hours, he estimates at 33 ounces and 2 drachms; and Sauvages, in the south of France, found that when the ingesta were 60 ounces in the day, the transpiration amounted to 33 ounces; the urine to 22; and the fæces to 5.

Most of these estimates were made in the cooler climates,—the "*regiones boreales*,"—as Haller has, not very happily, termed them.

According to Lining, whose experiments were made in South Carolina, lat. 32° 47′, the perspiration exceeded the urine in the warm months; but in the cold, the latter had the preponderance. The following table gives the average daily proportion of the urine and perspiration, for each month of the year, in ounces,—as quoted by Haller.

	Urine.	Perspiration.
December,	70.81	42.55
January,	72.43	39.97
February,	77.86	37.45
March,	70.59	43.23
April,	59.17	47.72
May,	56.15	58.11

	Urine.	Perspiration.
June,	52.90	71.39
July,	43.77	86.41
August,	55.41	70.91
September,	40.60	77.09
October,	47.67	40.78
November,	63.16	40.97

After the period at which Haller wrote, no experiments of any moment were adopted for appreciating the transpiration. Whenever trials were instituted, the exhalation from both the skin and the lungs was included in the result, and no satisfactory means were adopted for separating them, until Lavoisier and Séguin made their celebrated experiments.

Séguin inclosed himself in a bag of gummed taffeta, which was tied above the head, and had an aperture, the edges of which were fixed around the mouth by a mixture of turpentine and pitch. By means of this arrangement, the pulmonary transpiration alone escaped into the air. To estimate its quantity, it was merely necessary for M. Séguin to weigh himself in the sack, in a very delicate balance, at the commencement and termination of the experiment. By repeating the experiment out of the sack, he determined the total quantity of the transpired fluid; so that, by deducting from this the quantity of fluid exhaled from the lungs, he obtained the amount of the cutaneous transpiration. He, moreover, kept an account of the food, which he took; of the solid and liquid egesta; and, as far as he was able, of every circumstance that could influence the transpiration.

The results, as applicable to Paris, at which Lavoisier and Séguin arrived, by a series of well-devised and well-conducted experiments, were the following:—

First. Whatever may be the quantity of food taken, or the variations in the state of the atmosphere, the same individual, after having increased in weight by the whole quantity of nourishment taken, returns daily, after the lapse of twenty-four hours, to nearly the same weight as the day before; provided he be in good health; his digestion perfect; that he is not fattening, or growing; and he avoids all kinds of excess. *Secondly.* If, when all other circumstances are identical, the quantity of food varies; or if—the quantity of food being the same—the effects of transpiration differ; the quantity of the excrements augments or diminishes, so that every day, at the same hour, we return nearly to the same weight;—proving, that when digestion goes on well, the causes, which concur in the loss or excretion of the food taken in, afford each other mutual assistance;—in the state of health one charging itself with what the other is unable to accomplish. *Thirdly.* Defective digestion is one of the most direct causes of the diminution of transpiration. *Fourthly.* When digestion goes on well, and the other causes are equal, the quantity of

food has but little effect on the transpiration. Séguin affirms, that he has very frequently taken, at dinner, two pounds and a half of solid and liquid food; and, at other times, four pounds; yet the results, in the two cases, differed but little from each other; provided only, that the quantity of fluid did not vary materially in the two cases. *Fifthly.* Immediately after dinner, the transpiration is at its minimum. *Sixthly.* When all other circumstances are equal, the loss of weight, induced by insensible transpiration, is at its maximum during digestion. The increase of transpiration, during digestion, compared with the loss sustained when fasting, is, on an average, $2\frac{3}{10}$ grains per minute. *Seventhly.* When circumstances are most favourable, the greatest loss of weight, caused by insensible transpiration, was, according to their observations, 32 grains per minute; consequently 3 ounces, 2 drachms and 48 grains, *poids de marc*, per hour; and 5 pounds in twenty-four hours; under the calculation, that the loss is alike at all hours of the day, which is not, however, the fact. *Eighthly.* When all the accessory circumstances are least favourable, provided only that digestion is properly accomplished, the smallest loss of weight is 11 grains per minute; consequently, 1 ounce, 1 drachm and 12 grains per hour; and 1 pound, 11 ounces and 4 drachms in the twenty-four hours. *Ninthly.* Immediately after eating, the loss of weight, caused by the insensible perspiration, is $10\frac{1}{5}$ grains per minute, during the time at which all the extraneous causes are most unfavourable to transpiration; and $19\frac{1}{10}$ grains per minute, when these causes are most favourable and the internal causes are alike. "These differences," says M. Séguin, "in the transpiration after a meal, according as the causes, influencing it, are more or less favourable, are not in the same ratio with the differences, observed at any other time, when the other circumstances are equal; but we know not how to account for the phenomenon." *Tenthly.* The cutaneous transpiration is immediately dependent both on the solvent virtue of the circumambient air, and on the power possessed by the exhalants of conveying the perspirable fluid as far as the surface of the skin. *Eleventhly.* From the average of all the experiments it seems, that the loss of weight caused by the insensible transpiration is 18 grains per minute; and that, of these 18 grains, 11 on the average, belong to the cutaneous transpiration, and 7 to the pulmonary. *Twelfthly.* The pulmonary transpiration, compared with the volume of the lungs, is much more considerable than the cutaneous, compared with the surface of the skin. *Thirteenthly.* When every other circumstance is equal, the pulmonary transpiration is nearly the same before and immediately after a meal; and if, on an average, the pulmonary transpiration be $17\frac{1}{5}$ grains per minute before dinner, it is $17\frac{7}{10}$ grains after dinner. *Lastly.* Every other intrinsic circumstance being equal, the weight of the solid excrements is least during winter.

Although these results are probably fairly deduced from the experiments; and the experiments themselves were almost as well

conceived as the subject admits of, we cannot regard the estimates as more than approximations. Independently of the fact, that the envelope of taffeta must necessarily have retarded the exhalation by shutting off the air, and caused more to pass off by pulmonary transpiration; the perspiration must incessantly vary according to circumstances within and without the system; some individuals, too, perspire more readily than others; and this is dependent, as we have seen, upon climate and season,—and likewise upon the quantity of fluid received into the digestive organs. From all these and other causes, Bichat is led to observe, that the endeavour to determine the quantity of the cutaneous transpiration is as vain as to endeavour to specify what quantity of water is evaporated every hour, by a fire, the intensity of which is varying every instant.

To attempt, however, the solution of the problem, experiments were likewise undertaken by Cruikshank, and by Abernethy. Their plan consisted in confining the hand, for an hour, in an air tight glass jar, and collecting the transpired moisture. Mr. Abernethy, having weighed the fluid collected in the glass, multiplied its quantity by $38\frac{1}{2}$, the number of times he conceived the surface of the hand and wrist to be contained in the whole cutaneous surface. This gave $2\frac{1}{2}$ pounds, as the quantity exhaled from the skin in the twenty-four hours, upon the supposition, that the whole surface perspires to an equal extent. Of late, these experiments have been repeated by Dr. William Wood, of Newport, England, with some modifications. He pasted around the mouth of a jar one extremity of a bladder, the ends of which were cut away, and the hand being passed through the bladder into the jar, the other extremity was bound to the wrist with a ligature,—not so tight, however, as to interfere, in any degree, with the circulation. The exact weight of the jar and bladder had previously been ascertained. During the experiment, cold water was applied to the outer surface of the jar, to cause the deposition of the fluid accumulated within. The result of his experiments was as follows:—

Exp.	Time of day.	Temperature in apartment.	Pulse per minute.	Fluid collected in an hour.
1.	noon.	66°	84	32 grains.
2.	Do.	66	78	32
3.	Do.	66	78	26
4.	Do.	61	84	32
5.	9 P. M.	62	80	26
6.	Do.	62	75	23
	Mean.	63.8	79.8	28.5

The next thing was to estimate the proportion, which the surface of the hand and wrist bears to the whole surface of the body. Abernethy reckoned it as 1 to $38\frac{1}{2}$, whilst Cruikshank computed it

as 1 to 60! Dr. Wood does not adopt the estimate of either. He thinks, however, that the estimate of the former as regards the surface of the hand and wrist, which he makes seventy square inches, is near the truth, having found it to correspond both with his own measurements, and the reports of the glovers. Mr. Abernethy's estimate of the superficial area of the whole body—2700 square inches, or above eighteen square feet, he properly regards as too high. Perhaps the more general opinion is, that it amounts to sixteen square feet, or, 2304 square inches; but Haller did not think it exceeded thirteen square feet or 2160 square inches. Dr. Wood adopts the former of these, and is disposed to think, that the proportion of the surface of the hand and fingers, taken to the extremity of the bone of the arm, does not fall short of 1 to 2, which, if we adopt the ratio of the quantity, that he found transpired per hour, gives, for the whole body, about forty-five ounces, or nearly four pounds troy in the twenty-four hours. This is considerably above the result of the experiments of either Séguin, or Abernethy; but yet, on reviewing the experiments, Dr. Wood is not disposed to think it far from the truth.

Upwards of fifty years ago, Mr. Dalton of Manchester, undertook a series of experiments similar to those of Sanctorius, Keil, Hartmann and Dodart; the results of, and inferences from, which, he has published of late in the fifth volume of the memoirs of the *Literary and Philosophical Society of Manchester*. The first series of experiments he made upon himself, in the month of March, for fourteen days in succession. The aggregate of the articles of food consumed in this time was as follows;—bread, 163 ounces avoirdupois; oaten cake, 79 ounces; oatmeal, 12 ounces; butcher's meat, $54\frac{1}{2}$ ounces; potatoes, 130 ounces; pastry 55 ounces; cheese, 32 ounces;—Total of solid food, $525\frac{1}{2}$ ounces; averaging 38 ounces daily: of milk, $435\frac{1}{2}$ ounces; beer, 230 ounces; tea, 76 ounces;—Total, $741\frac{1}{2}$, averaging 53 ounces of fluid daily. The daily consumption was, consequently, 91 ounces; or nearly six pounds. During the same period, the total quantity of urine passed was 680 ounces; and of fæces, 68 ounces;—the daily average being,—of urine, $48\frac{1}{2}$ ounces; of fæces, 5 ounces; making $53\frac{1}{2}$. If we subtract these egesta from the ingesta, there will remain $37\frac{1}{2}$ ounces, which must have been exhaled by the cutaneous and pulmonary transpirations, on the supposition that the weight of the body remained stationary.

To test the influence of difference of seasons, Mr. Dalton resumed his investigations, in the month of June of the same year. The results were as might have been anticipated,—a less consumption of solids and a greater of fluids; a diminution in the evacuations and an increase in the insensible perspiration. The average of solids, consumed per day, was 34 ounces; of fluid, 56 ounces;—total, 90 ounces; the daily average of the evacuations,—urine, 42 ounces; fæces, $4\frac{1}{3}$,—leaving a balance of nearly 44 ounces, for the daily loss by perspiration, or one-sixth more than during the cooler season.

Mr. Dalton next varied the process, with the view of obtaining

the quantity of perspiration, and the circumstances attendant upon it more directly. He procured a weighing beam, that would turn with one ounce. Dividing the day into periods of four hours in the forenoon, four or five hours in the afternoon, and nine hours in the night,—or from ten o'clock at night to seven in the morning, he endeavoured to find the perspiration corresponding to these periods respectively. He weighed himself directly after breakfast, and again before dinner, observing neither to take nor part with anything in the interval, except what was lost by perspiration. The difference in weight indicated such loss. The same course was followed in the afternoon and in the night. This train of experiments was continued for three weeks in November. The mean hourly losses by transpiration were;—in the morning, 1.8 ounces avoirdupois;—afternoon, 1.67 ounces;—night, 1.5 ounces. During twelve days of this period, Mr. Dalton kept an account of urine corresponding in time with perspiration. The ratio was as 46 to 33.

From the whole of his investigation on this subject, Mr. Dalton concludes;—that of six pounds of aliment taken in the day, there appears to be nearly one pound of carbon and azote together, the remaining five pounds are chiefly water, which seems necessary as a vehicle to introduce the other two elements into the circulation, and also to supply the lungs and other membranes with moisture; that very nearly the whole quantity of food enters the circulation, for the fæces constitute only $\frac{1}{18}$th part, and of these a part—bile—must have been secreted; that one great portion is thrown off by the kidneys,—namely, about half of the whole weight taken, but probably more or less according to climate, season, &c.; that another great portion is thrown off by means of insensible perspiration, which may be subdivided into two portions, one of which passes off by the skin—amounting to one-sixth part, and the other five-sixths are discharged from the lungs in the form of carbonic acid, and of water or aqueous vapour.

Since the time of Lavoisier and Séguin, Dr. Edwards has made some experiments, for the purpose of illustrating the effect produced upon cutaneous transpiration by various circumstances to which the body is subjected. His first trials were made on cold-blooded animals, in which the cutaneous transpiration can be readily separated from the pulmonary, owing to the length of time, that they are capable of living without respiring. All that is necessary is to weigh the animal before and after the experiment, and to make allowance for the ingesta and egesta.

In this way he discovered, that the body loses successively less and less in equal portions of time; that the transpiration proceeds more rapidly in dry than in moist air; in the extreme states nearly in the proportion of 10 to 1; that temperature has, also, considerable influence,—the transpiration, at 68° of Fahrenheit, being twice as much; and, at 104°, seven times as much as at 32°. He likewise found, that frogs transpire, whilst they are in water, as is shown by the diminution, which they experience while immersed

in that fluid, and by the appearance of the water itself, which becomes perceptibly inpregnated by the matter excreted by the skin.

In warm-blooded animals, he found, as in the cold-blooded, the transpiration become less and less in proportion to the quantity of fluid evaporated from the body; and he observed the same difference between the effects of moist and dry air, and between a high and a low temperature. The effects of these agents were essentially the same on man as on other animals. He found, that the transpiration was more copious during the early than the latter part of the day; that it is greater after taking food; and, on the whole, appeared to be increased during sleep.

Whenever the fluid, which constitutes the insensible transpiration, does not evaporate, owing to the causes referred to at the commencement of this article, it appears on the surface in the form of *sensible perspiration* or *sweat.* It has been supposed by some physiologists, that the insensible and sensible perspirations are two distinct functions. Such appears to be the opinion of Haller, and of Edwards, who regards the former as a physical *evaporation*,—the latter as a vital *transudation;* but no sufficient reason seems to exist, why we should not regard them as different degrees of the same function. It is, indeed, affirmed, that the sweat is generally less charged with carbonic acid than the vapour of transpiration: it is richer in salts, which are deposited on the skin, and are sometimes seen in the form of white flocculi; our knowledge on this matter is, however, vague.

Particular parts of the body perspire more freely, and sweat more readily than others. The forehead, armpits, groins, hands, feet, &c. exhibit evidences of this most frequently; some of these, perhaps, owing to the fluid, when exhaled, not evaporating readily,—the contact of air being impeded. It is presumed, likewise, that the sweat has not everywhere the same composition. Its odour certainly varies in different parts of the body. In the armpits and feet it is more acid: in the violent sweats, accompanying acute rheumatism, this acidity always attracts attention; and in the groins, its odour is strong and rank. It differs too greatly in individuals, and especially in the races. In the red-haired, it is said to be unusually strong; and in the negro, during the heat of summer, it is alliaceous and overwhelming. By cleanliness, the red-haired can obviate the unpleasant effects, in a great measure, by preventing undue accumulation in the axillæ, groins, &c.; but no ablution can remove the odour of the negro, although cleanliness can detract from its intensity. Each race appears to have its characteristic scent; and, according to Humboldt, the Peruvian Indian, whose smell is highly developed by education, can distinguish the European, the American Indian, and the negro, in the middle of the night, by this sense alone.

Some physiologists have doubted whether the odorous matter of the skin belongs properly to the perspiration, and have presumed it

to be the product of specific organs. This is, however, conjectural; and the experiments of Thénard, as well as the facts we have just mentioned, would rather seem to show, that the matter of sweat itself has, within it, the peculiar odour. The fact of the dog tracing its master to an immense distance, and discovering him, perhaps, in a crowd, has induced a belief, that the scent may be distinct from the matter of sweat; but the supposition is not necessary, if we admit the matter of perspiration to be itself odorous.

Besides the causes before referred to, the quantity of perspiration is greatly augmented by running or by violent exertion of any kind; especially if the temperature of the air be elevated. Warm fluids favour it greatly, and hence their use, alone or combined with sudorifics, where this class of medicines is indicated. Magendie conceives, that being readily absorbed, they are also readily exhaled. This may be true; but the perspiration breaks out too rapidly to admit of this explanation. When ice-cold drinks are taken in hot weather, the cutaneous transpiration is instantaneously excited. The effect, consequently, must be produced by the refrigerant influence of the cold medium on the lining membrane of the stomach,—this influence being propagated, by sympathy, to every part of the capillary system. The same explanation is applicable to warm drinks, whilst the hot exert a sympathetic effect on the skin by virtue of their stimulant properties exerted on the mucous membrane.

With regard to the uses of the insensible transpiration, it has been supposed to preserve the surface supple, and thus to favour the exercise of touch; and also, by undergoing evaporation, to aid in the refrigeration of the body. It is probable, however, that these are quite secondary uses under ordinary circumstances, and that the great office, performed by it, is to remove a certain quantity of fluid from the blood: hence it has been properly termed the *cutaneous depuration*. In this respect, it bears a striking analogy to the urine, which is the only other depuratory secretion, with the exception of the pulmonary transpiration, which, we shall find, essentially resembles the cutaneous.

Being depuratory, it has been conceived, that any interruption to the transpiration must be attended with the most serious consequences; accordingly, most diseases have, from time to time, been ascribed to this cause. There is, however, so great a compensation existing between the urinary and cutaneous depurations, that if one be augmented the other is decreased,—and conversely. Besides, it is well-known, that disease is more apt to be induced by partial and irregular application of cold than by frigorific influences of a more general character. The Russian vapour-bath exemplifies this; the bather frequently passing with impunity from a temperature of 130° into cold water. The morbific effect—in these cases of fancied check given to perspiration—is derangement of the capillary vessels engaged in the important functions of nutrition,

calorification, and secretion, and the extension of this derangement to every part of the system.*

As the *sensible transpiration* or *sweat* is probably only the insensible perspiration in increased quantity, with the addition of salts, and other matters that are not evaporable, its uses demand no special notice.

The PULMONARY TRANSPIRATION, to which we have so often alluded, bears a striking analogy to the cutaneous. At one time, it was universally believed to be owing to the combustion of the air with the hydrogen and carbon given off from the lungs; but we have elsewhere shown, that no such combustion occurs; and, besides, the exhalation takes place, when gases, containing no oxygen, have been respired by animals.

It is now universally admitted to be exhaled into the air-cells of the lungs from the pulmonary artery chiefly, but partly from the bronchial arteries, distributed to the mucous membrane of the air-passages. Much of the vapour, Dr. Prout conceives, is derived from the chyle in its passage through the lungs; and thus, he thinks, the weak and delicate albumen of the chyle is converted into the strong and perfect albumen of the blood.

Several interesting experiments have been made on this exhalation, by Magendie, Milne Edwards, Breschet, and others. If water be injected into the pulmonary artery, it passes into the air-cells, in myriads of almost imperceptible drops, and mixes with the air contained in them.

Magendie found, that its quantity might be augmented at pleasure on living animals, by injecting distilled water, at a temperature approaching that of the body, into the venous system. He injected into the veins of a small dog, a considerable amount of water. The animal was at first in a state of real plethora, the vessels being so much distended that it could scarcely move; but, in a few minutes, the respiration became manifestly hurried, and a large quantity of fluid was discharged from the mouth, the source of which appeared evidently to be in the pulmonary transpiration considerably augmented.

Not only, however, is the aqueous portion of the blood exhaled in this manner: experiment shows, that many substances, introduced into the veins by absorption, or by direct injection, issue by the lungs. Weak alcohol, a solution of camphor, ether and other odorous substances, when thrown into the cavity of the peritoneum or elsewhere, were found, by Magendie, to be speedily absorbed by the veins, and conveyed to the lungs, where they transuded into the bronchial cells, and were recognized by the smell in the expired air.

* This subject will be expatiated upon in a forthcoming work, by the author, on 'General Therapeutics.'—See also 'Elements of Hygiène,' p. 69.

Phosphorus, when injected, exhibited this transmission in a singular and evident manner.

Magendie, on the suggestion of M. Armand de Montgarny, "a young physician," he remarks, "of much merit," now no more, injected into the crural vein of a dog, half an ounce of oil, in which phosphorus had been dissolved; scarcely had he finished the injection, before the animal sent through the nostrils clouds of a thick, white vapour, which was phosphorous acid. When the experiment was made in the dark, these clouds were luminous.

More lately, MM. Breschet and Milne Edwards have made several experiments, for the purpose of discovering, why the pulmonary transpiration expels so promptly the different gaseous and liquid substances received into the blood. Considering properly, that exhalation differs only from absorption in taking place in an inverse direction, these gentlemen conjectured, that it ought to be accelerated by every force, that would attract the fluids from within to without; and such a force they conceive inspiration to be, which, in their view, solicits the fluids of the economy to the lungs, in the same mechanical manner as it occasions the entrance of the air into the air-cells. In support of this view, they adduce the following experiments.

1. To the trachea of a dog, a pipe, communicating with a bellows, was adapted, and the thorax was largely opened. Natural respiration was immediately suspended; but artificial respiration was kept up by means of the bellows. The surface of the air-cells was, in this way, constantly subjected to the same pressure; there being no longer diminished pressure during inspiration, as when the thorax is sound, and the animal breathing naturally. Six grains of camphorated spirit were now injected into the peritoneum of the animal; and, at the same time, a similar quantity was injected into another dog, whose respiration was natural. In the course of from three to six minutes, the odorous substance was detected in the pulmonary transpiration of the latter; but in the other it was never manifested.

In the first animal, they now exposed a part of the muscles of the abdomen, and applied a cupping-glass to it; when the smell of the camphor speedily appeared at the cupped surface. Their conclusion was, that the pulmonary surface, having ceased to be subjected to the suction force of the chest, during inspiration, the exhalation was arrested, whilst that of the skin was developed as soon as an action of aspiration was exerted upon it by the cupping-glass.

2. Into the crural veins of two dogs;—one of which breathed naturally, and the other was circumstanced as in the last experiment, —they injected the essential oil of turpentine. In the first of these, the substance was soon apparent in the pulmonary transpiration; and, on opening the body, it was discovered, that the turpentine had impregnated the lung and the pleura much more strongly than the

other tissues. In the other animal, on the contrary, the odour of the turpentine was scarcely apparent in the vapour of the lungs; and, on dissection, it was not found in greater quantity in the lungs than in the other issues;—in the pleura than in the peritoneum.

From the results of these experiments, MM. Breschet and Edwards conclude, that each inspiratory movement constitutes a kind of suction, which attracts the blood to the lungs; and which causes the ejection, through the pulmonary surface, of the liquid and gaseous substances that are mingled with that fluid, more than through the other exhalant surfaces of the body.

In their experiments, these gentlemen did not find that the exhalation was effected with equal readiness in every part of the surface, when the cupping-glass was applied in the manner that has been mentioned. The skin of the thigh, for example, did not indicate the odour of camphorated alcohol, as that of the region of the stomach.

The chymical composition of the pulmonary transpiration is probably nearly identical with that of the sweat; appearing to consist of water, holding in solution, perhaps, some saline and albuminous matter; but our information, on this matter, derived from the chymist, is not precise. Chaussier found, that by keeping a portion of it in a close vessel, exposed to an elevated temperature, a very evident putrid odour was exhaled on opening the vessel. This could only have arisen from the existence of animal matter in it.

The pulmonary transpiration being liable to all the modifications which affect the cutaneous, it is not surprising, that we should meet with so much discordance in the estimates of different individuals, regarding its quantity in a given time. Hales valued it at 20 ounces in the twenty-four hours; Sanctorius, Menzies and Dr. William Wood, at 6 ounces; Abernethy at 9 ounces; Lavoisier and Seguin at $17\frac{1}{2}$ ounces, *poids de marc;* Thomson at 19 ounces, and Dalton at 1 pound $8\frac{3}{4}$ ounces.

The uses it serves, in the animal economy, are identical with those of the cutaneous depuration.

9. *Exhalation of the Mucous Membranes.*

The mucous membranes, like the skin, which they so strongly resemble in their structure, functions and diseases, exhale a similar transpiratory fluid; which has not, however, been subjected to chymical examination. It is, indeed, almost impracticable to separate it from the follicular secretions, poured out from the same membrane; and from the extraneous substances, almost always in contact with it. It is probably, however, similar to the fluid of the cutaneous and pulmonary depurations, both in character and use.

Sect. II.—Follicular Secretions.

The *follicular secretions* must, of necessity, be effected from the skin or the mucous membranes; as the follicles or crypts are met with there only. They may, therefore, be divided into two classes: —1st, the *mucous follicular secretion;* and 2d, the *cutaneous follicular secretion.*

1. *Mucous Follicular Secretion.*

The whole extent of the great mucous membranes,—lining the alimentary canal, the air-passages and the urinary and genital organs,—is the seat of a secretion, the product of which has received, in the abstract, the name of *mucus;* although it differs somewhat according to the situation and character of the particular follicles, whence it proceeds. Still, essentially, the structure, functions and product are the same. According to M. Donné, its character is alkaline in health; in disease often acid.

In the history of the different functions, in which some of the mucous membranes are concerned, the uses of this secretion have been detailed; and in those that will hereafter have to engage attention, in which other mucous membranes are concerned, their uses will fall more conveniently under notice then. But few points will, therefore, require explanation at present.

The mucus, secreted by the nasal follicles, seems alone to have been subjected to chymical analysis. Fourcroy and Vauquelin found it composed of precisely the same ingredients as the tears. According to the analysis of Berzelius, its contents are as follows:—water, 933.7; mucus, 53.3; muriates of potassa and soda, 5.6; lactate of soda, with animal matter, 3.0; soda, 0.9; albumen and animal matter, soluble in water, but insoluble in alcohol, with a trace of phosphate of soda, 3.5. According to Raspail, mucus is the mere product of the healthy and daily disorganization, or wear and tear of the mucous membranes. Every mucous membrane, he affirms, exfoliates in organized layers, and is thrown off, more or less, in this form; whilst the serous membranes either do not exfoliate, or their exfoliation (*excoriation*) is resolved into the liquid form, to be again absorbed by the organs; but this—like many other of M. Raspail's speculations—is a generalization which does not appear to be warranted by the facts; the slightest examination, indeed, exhibits, that the general physical character of the mucus is very different from that of the membranes which form it: still mucus, when examined by a microscope of high magnifying powers—and this the author had an opportunity of doing through the kindness of Dr. Weldon, by his hydro-oxygen microscope—does present, here and there, appearances of shreds similar to those described by Raspail.

The great use of mucus, wherever met with, is to lubricate the surface on which it is poured.

2. *Follicular Secretion of the Skin.*

This is the sebaceous and micaceous humour, observed in the skin of the cranium, and in that of the pavilion of the ear. It is also the humour, which occasionally gives the appearance of small worms beneath the skin of the face, when it is forced through the external aperture of the follicle; and which, when exposed to the air, causes the black spots sometimes observable on the face. The cerumen is, likewise, a follicular secretion, as well as the whitish, odorous and fatty matter, which forms under the prepuce of the male, and in the external parts of the female, where cleanliness is disregarded. The humour of Meibomius is also follicular, as well as that of the caruncula lachrymalis. The use of this secretion is,—to favour the functions of the part over which it is distributed. That, which is secreted from the skin, is spread over the epidermis, hair, &c., giving suppleness and elasticity to the parts, rendering the surface smooth and polished, and thus obviating the evils of abrasion that might otherwise arise. It is also conceived, that its unctuous nature may render the parts less permeable to humidity.

Sect. III.—Glandular Secretions.

The glandular secretions are seven in number;—those of the tears, saliva, pancreatic juice, bile, urine, sperm, and milk.

1. *Secretion of the Tears.*

The lachrymal apparatus, being a part of that accessory to vision, was described under that head. As we meet with the tears, they are not simply the secretion of the lachrymal gland, but of the conjunctiva, and occasionally of the caruncula lachrymalis and follicles of Meibomius. They have a saline taste; mix freely with water; and, owing to the presence of free soda, communicate a green tint to the blue infusion of violets. Their chief salts are the muriate, and phosphate of soda. According to Fourcroy and Vauquelin, the animal matter of the tears is mucus; but it is presumed, by some, to be albumen or an analogous principle.

This secretion is more influenced by the emotions than any other; and hence it is concerned in the expressions of lively joy and sorrow, especially of the latter.

2. *Secretion of the Saliva.*

The salivary apparatus has, likewise, engaged attention elsewhere. It consists of a *parotid* gland on each side, situated in front of the ear, and behind the neck and ramus of the jaw; a *submaxillary*, beneath the body of the bone; and a *sublingual*, situated immediately

beneath the tongue,—the parotids and submaxillary glands having each but one excretory duct;—the sublingual several.

All these ducts pour the fluid of their respective glands into the mouth, where it collects, and becomes mixed with the exhalation from the mucous membrane of the mouth, and the secretion from its follicles. It is this mixed fluid, that has been generally analyzed by the chymist.

According to Berzelius, its constituents are,—water, 992.2; peculiar animal matter, 2.9; mucus, 1.4; muriates of potassa and soda, 1.7; lactate of soda, and animal matter, 0.9; soda, 0.2. Drs. Bostock and Thomas Thomson think, that the "mucus" of Berzelius resembles coagulated albumen in its properties. In the tartar of the teeth, which seems to be a sediment from the saliva, Berzelius found 79 parts of earthy phosphate; 12.5 of undecomposed mucus; 1 part of a matter peculiar to the saliva, and 7.8 of an animal matter soluble in muriatic acid. This animal matter, according to the microscopic experiments of Raspail, is composed of deciduous fragments from the mucous membrane of the cavity of the mouth; and he considers that the saliva is nothing more than an albuminous solution, mixed with different salts, which are capable of more or less modifying its solubility in water, and of shreds or layers of tissue.

MM. Leuret and Lassaigne analyzed *pure* saliva, obtained from an individual labouring under salivary fistula, and found it to contain,—water, mucus, traces of albumen, soda, chloride of potassium, chloride of sodium, carbonate and phosphate of lime;—and Messrs. Tiedemann and Gmelin affirm, that the saliva contains only one or two-hundredths of solid matter, which are composed of a peculiar substance, called *salivary matter;* osmazome; mucus; perhaps albumen; a little fat, containing phosphorus; and the insoluble salts—phosphate and carbonate of lime. Besides these, they detected the following soluble salts;—acetate, carbonate, phosphate, sulphate, and muriate of potassa, and the sulpho-cyanate of potassa.

As the salivary secretion forms an important part in the processes preparatory to stomachal digestion, its uses have been detailed in the first volume of this work.

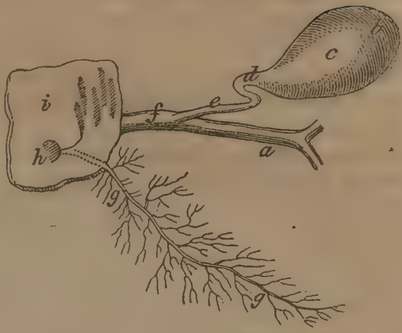
3. *Secretion of the Pancreatic Juice.*

The *pancreas* or *sweatbread*, Fig. 138, G., secretes a juice or humour, called *succus pancreaticus* or *pancreatic juice.* Its texture resembles that of the salivary glands; and hence it has been called, by some, the *abdominal salivary gland.* It is situated transversely in the abdomen, behind the stomach, towards the concavity of the duodenum; is about six inches long; of a reddish-white colour, and firm consistence. Its excretory ducts terminate in one,—called the duct of Wirsung,—which opens into the duodenum, at times separately from the ductus communis choledochus,

but close to it; at other times, being confounded with, or opening into, it.

The quantity of fluid, secreted by the pancreas, does not seem to be considerable. Magendie, in his experiments, was struck with the small quantity discharged. Frequently, scarcely a drop issued in half an hour; and, occasionally, a much longer time elapsed. Nor did he find that the flow, according to the common opinion and to probability, was more rapid whilst digestion was going on.

Fig. 137.



Biliary and pancreatic ducts.

a. The hepatic duct, formed by a branch from the right, and one from the left lobe of the liver.—*b*. Fundus of gall-bladder.—*c*. *d*. Body and neck of gall-bladder.—*e*. Cystic duct.—*f*. Ductus communis choledochus.—*g*. *g*. Trunk and branches of the pancreatic duct.—*h*. Termination of the ductus communis choledochus and the ductus pancreaticus.—*i*. The duodenum.

It will be readily understood, therefore, that it cannot be an easy task to collect it. De Graaf, a Dutch anatomist, affirms, that he succeeded by introducing, into the intestinal end of the excretory duct, a small quill, terminating in a phial fixed under the belly of the animal. Magendie, however, states, that he tried this plan several times but without success; and he believes it to be impracticable. The plan he adopts is to expose the intestinal orifice of the duct; to wipe, with a fine cloth, the surrounding mucous membrane; and, as soon as a drop of the fluid oozes, to suck it up by means of a *pipette* or small glass tube. In this way, he collected a few drops, but never sufficient to undertake a satisfactory analysis.

Messrs. Tiedemann and Gmelin make an incision into the abdomen; draw out the duodenum, and a part of the pancreas; and, opening the excretory duct, insert a tube into it; and a similar plan was adopted successfully on a horse by MM. Leuret and Lassaigne.

The difficulty, experienced in collecting a due quantity, is a probable cause of some of the discrepancy amongst observers, regarding its sensible and chymical properties.

Some of the older physiologists affirm it to be acidulous and saline; others assert that it is alkaline.

The majority of those of the present day compare it to the saliva, and affirm it to be inodorous, insipid, viscid, limpid, and of a bluish white colour. The latest experimenters by no means accord with each other.

According to Magendie, it is of a slightly yellowish hue, saline taste, devoid of smell, occasionally alkaline, and partly coagulable by heat.

MM. Leuret and Lassaigne found that of the horse—of which they

obtained three ounces,—to be alkaline, and composed of 991 parts of water in 1000; of an animal matter, soluble in alcohol; another, soluble in water; traces of albumen and mucus; free soda; chloride of sodium; chloride of potassium, and phosphate of lime.

In their view, consequently, the pancreatic juice strongly resembles saliva.

MM. Tiedemann and Gmelin succeeded in obtaining upwards of two drachms of the juice in four hours; and, in 100 parts, they found from five to eight solid. These solid parts consisted of osmazome; a matter which became red by chlorine; another analogous to caseine, and probably associated with salivary matter; much albumen; a little free acid, probably the acetic; the acetate, phosphate, and sulphate of soda, with a little potassa; chloride of potassium, and carbonate and phosphate of lime:—so that, according to these gentlemen, the pancreatic juice differs from the saliva in containing;—a little free acid, whilst the saliva is alkaline; much albumen, and matter resembling caseine; but little mucus and salivary matter, and no sulpho-cyanate of potassa.

The precise use of the pancreatic juice in digestion—as we have previously seen—is not determined.

4. *Secretion of the Bile.*

The biliary secretion is, also, a digestive fluid, of which we have spoken in the appropriate place. The mode, however, in which the process is effected, has not yet been investigated.

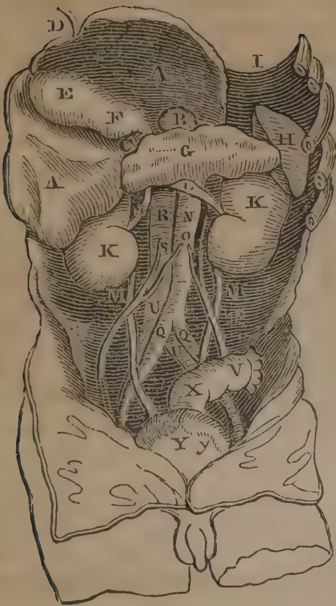
The apparatus consists of the *liver*, which accomplishes the formation of the fluid; the *hepatic duct*,—the excretory channel, by which the bile is discharged: the *gall-bladder*, in which a portion of the bile is retained for a time; the *cystic duct*—the excretory channel of the gall-bladder; and the *ductus communis choledochus*, or *choledoch duct*, formed by the union of the hepatic and cystic ducts, and which conveys the bile immediately into the duodenum.

The *liver*, A, A, Fig. 103, and A, A, Fig. 138, is the largest gland in the body; situated in the abdomen, beneath the diaphragm, above the stomach, the arch of the colon, and the duodenum; filling the whole of the right hypochondrium, and more or less of the epigastrium, and fixed in its situation by duplicatures of the peritoneum, called *ligaments of the liver.*

The weight of the human liver is generally, in the adult, about three or four pounds. In disease, however, it sometimes weighs twenty or twenty-five pounds; and, at other times, not as many ounces. Its shape is irregular, and it is divided into three chief lobes, the *right*, the *left*, and the *lobulus spigelii.* Its upper convex surface touches everywhere the arch of the diaphragm. The lower concave surface corresponds to the stomach, colon, and right kidney.

At the concave surface, two *fissures* are observable;—the one

Fig. 138.



Abdominal and Pelvic Viscera.

A, A. Concave surface of liver turned upwards, and to the right side.—B. Lobulus spigelii.—Between B and C, the porta of the liver.—D. Ligamentum rotundum.—E, F. Gall-bladder.—G. The pancreas.—H. The spleen.—I. The ribs.—K, K. The kidneys.—L, L. Renal veins.—M, M. Ureters.—N. Aorta.—O. Spermatic arteries.—Q, Q. Common iliac arteries.—R. Vena cava.—S. The spermatic vein.—U, U. Common iliac veins.—V. End of colon.—X. Commencement of the rectum.—Y, y. Urinary bladder.

passing from before to behind, and lodging the umbilical vein in the fœtus—called the *horizontal sulcus* or *fissure, great fissure*, or *fossa umbilicalis;* the other, cutting the last at right angles, and running from right to left, by which the different nerves and vessels proceed to and from the liver, and called the *principal fissure*, or *sulcus transversus*.

The liver itself is composed of the following anatomical elements:—1. The *hepatic artery*, a branch of the cœliac, which ramifies minutely through the substance of the organ. The minuter branches of this artery are arranged somewhat like the hairs in a painter's brush, and have hence been called the *penicilli* of the liver. Mr. Kiernan believes, that the blood, which enters the liver by the hepatic artery, fulfils three functions:—it nourishes the organ; supplies the excretory ducts with mucus; and, having fulfilled these objects, it becomes venous; enters the branches of the portal veins, and not the radicles of the hepatic, as usually supposed, and contributes to the secretion of bile. 2. The *vena porta*, which we have elsewhere seen to be the common trunk of all the veins of the digestive organs and of the spleen. It divides like an artery, its branches accompanying those of the hepatic artery. Where the vein lies in the transverse fissure, it is of great size, and has hence been called *sinus venæ portæ*. The possession of two vascular systems, containing blood, is peculiar to the liver, and has been the cause of some difference of opinion, with regard to the precise material—arterial or venous—from which the bile is derived. According to Mr. Kiernan, the portal vein fulfils two functions: it carries the blood from the hepatic artery, and the mixed blood to the coats of the excretory ducts. This vessel has been called the *vena arteriosa*, because it ramifies like an artery, and conveys blood for secreting: but, as Mr. Kiernan has observed, it is an *arterial vein* in another sense, as it is a vein to the hepatic artery, and an artery to the

hepatic veins. 3. The *excretory ducts*, or *biliary ducts*. These are presumed to arise from acini, communicating, according to some, with the extremities of the vena portæ; according to others, with the radicles of the hepatic artery; whilst others have considered, that the radicles of the hepatic ducts have blind extremities, and that the capillary blood-vessels, which secrete the bile, ramify on them. This last arrangement of the biliary apparatus in the liver was well shown in an interesting pathological case, which fell under the care of Professor Hall, in the Baltimore Infirmary, during the last spring, (1835) and which was examined after death, by Professor Geddings, in the Author's presence. The particulars of the case are detailed in the 9th No. of the 'North American Archives of Medical and Surgical Science,' with some interesting remarks by Professor Geddings. In this case, in consequence of cancerous matter obstructing the ductus communis choledochus, the whole excretory apparatus of the liver was enormously distended; the common duct was dilated to the size of the middle finger: at the point where the two branches that form the hepatic duct emerge from the gland, they were large enough to receive the tip of the middle finger; and as they were proportionately dilated to their radicles, in the intimate tissue of the liver, their termination in a blind extremity was clearly exhibited. These blind extremities were closely clustered together, and the ducts, proceeding from them, were seen to converge, and to terminate in the main trunk for the corresponding lobe.

At their commencement, the excretory ducts are termed *pori biliarii*. These ultimately form two or three large trunks, which issue from the liver by the transverse fissure, and end in the *hepatic duct*. 4. *Lymphatic vessels*. 5. *Nerves*, in small number, compared with the size of the liver, some proceeding from the eighth pair; but the majority from the solar plexus, and following the course and divisions of the hepatic artery. 6. The *supra-hepatic veins*, or *venæ cavæ hepaticæ*, which arise in the liver by imperceptible radicles, communicating, according to common belief, with the final ramifications of both the hepatic artery and venæ portæ. They return the superfluous blood, carried to the liver by these vessels, by means of two or three trunks, and six or seven branches, which open into the vena cava inferior. These veins generally pass, in a convergent manner, towards the posterior margin of the liver, and cross the divisions of the vena portæ at right angles. 7. The remains of the umbilical vein, which, in the fœtus, enters at the horizontal fissure. This vein, after respiration is established, becomes converted into a ligamentous substance, called, from its shape, *ligamentum rotundum*, or *round ligament*.

The parenchyma, formed by these anatomical elements, it is difficult to describe; and although the term *liver-coloured* is used in common parlance, it is not easy to say what are the ideas attached to it.

The organ has two coats;—the outer, derived from the peritoneum, which is very thin, transparent, easily lacerable, and vascular, and is the seat of the secretion, operated by serous membranes in general. It does not cover the posterior part, nor the excavation for the gall-bladder, the vena cava, nor the fissures in the concave surface of the liver. The inner coat is the proper membrane of the liver. It is thin, but not easily torn, and it covers not only every part of the surface of the liver, but also the large vessels that are proper to the organ. The condensed cellular substance,—which unites the sinus of the vena portæ and its two great branches, the hepatic artery, the common biliary duct, lymphatic glands, lymphatic vessels, and nerves in the transverse fossa or fissure of the liver,—was described by Glisson as a capsule; and hence has been called the *capsule* of Glisson.

The *gall-bladder*, (Figs. 103, 137, and 138,) is a small membranous pouch, of a pyriform shape, situated at the inferior and concave surface of the liver, to which it is attached, and above the colon and duodenum. A quantity of bile is usually found in it.

The gall-bladder is not met with in all animals. It is wanting in the elephant, horse, stag, camel, rhinoceros, and goat; in certain of the cetacea; in some birds, as the ostrich, pigeon, and parrot; and is occasionally deficient in man.

Its largest part or *fundus*, Figs. 137 and 138, is turned forwards; and, when filled, frequently projects beyond the anterior margin of the liver. Its narrowest portion, cervix, or neck is turned backwards, and terminates in the cystic duct. Externally, it is partly covered by the peritoneum, which attaches it to the liver, and to which it is, moreover, adherent by cellular tissue and vessels.

Internally, it is rugous; the folds being reticulated, and appearing somewhat like the cells of a honey-comb.

Anatomists have differed with regard to the number of coats proper to the gall-bladder. Some have described two only;—the peritoneal and mucous; others have added an intermediate cellular coat; whilst others have reckoned four;—a peritoneal coat;—a thin stratum of muscular fibres, passing in different directions, and of a pale colour,—a cellular coat, in which a number of blood-vessels is situated; and an internal mucous coat. The existence of the muscular coat has been denied by perhaps the generality of anatomists; but there is reason for believing in its existence. Amussat saw muscular fibres distinctly in a gall-bladder dilated by calculi; and Dr. Monro, the present Professor of Anatomy in the University of Edinburgh, asserts, that he has seen it contract, in a living animal, for half an hour, under mechanical irritation, and assume the shape of an hour-glass.

The mucous coat forms the rugæ to which we have already alluded. In the neck, and in the beginning of the cystic duct, there are from three to seven—sometimes twelve—semilunar duplicatures, which retard the flow of any fluid inwards or outwards. These are

sometimes arranged spirally, so as to form a kind of valve, according to Amussat.

On the inner-surface of the gall-bladder, especially near its neck, numerous follicles exist; the secretion from which it is said to fill the gall-bladder, when that of the bile has been interrupted by disease, as in yellow fever, scirrhus of the liver, &c.

The *hepatic duct*, Fig. 137, *a*, is the common trunk of all the excretory vessels of the liver; and makes its exit from that organ by the transverse fissure. It is an inch and a half in length, and about the diameter of an ordinary writing quill. It is joined, at a very acute angle, by the duct from the gall-bladder—the *cystic duct*, Fig. 137, *e*, to form the ductus communis choledochus. The cystic duct is about the same length as the hepatic.

The *ductus communis choledochus* is about three or three and a half inches long. It descends behind the right extremity of the pancreas, through its substance; passes for an inch obliquely between the coats of the duodenum, diminishing in diameter; and ultimately terminates by a yet more contracted orifice, on the inner surface of the intestine, at the distance of three or four inches from the stomach.

The structure of all these ducts is the same. The external coat is thick, dense, strong, and generally supposed to be of a cellular character; the inner is a mucous membrane, like that which lines the gall-bladder.

The secretion of the bile is probably effected like the other glandular secretions; but modified, of course, by the peculiar structure of the liver. We have seen, that the organ differs from every other secretory apparatus, in having two kinds of blood distributed to it:—arterial blood by the hepatic artery; and venous blood by the vena portæ. A question has consequently arisen—from which of these is the bile formed? Anatomical inspection throws no light on the subject; and, accordingly, argument is all that can be adduced on one side or the other.

The most common and the oldest opinion is, that the bile is separated from the blood of the vena portæ; and the chief reasons, adduced in favour of this belief, are the following. *First.* The blood of the portal system is better adapted than arterial blood for the formation of bile, on account of its having, like all venous blood, more carbon and hydrogen, which are necessary for the production of a humour as fat and oily as the bile; and it has been imagined, by some, that the blood, in crossing the omentum, becomes loaded with fat. *Secondly.* The vena portæ ramifies in the liver, after the manner of an artery, and evidently communicates with the secretory vessels of the bile. *Thirdly.* It is larger than the hepatic artery; and more in proportion to the size of the liver; the hepatic artery seeming to be merely for the nutrition of the liver, as the bronchial artery is for that of the lung.

In answer to these positions it has been argued; that there seems to be no more reason why the bile should be formed from venous blood than the other fatty and oleaginous humours—the marrow and fat, for example,—which are derived from arterial blood.

It is asked, again, whether, in fact, the blood of the vena portæ is more rich in carbon and hydrogen? and whether there is a closer chymical relation between the bile and the blood of the vena portæ, than between the fat and arterial blood? The notion of the absorption of fat from the omentum, it is properly urged, is totally gratuitous. *Secondly.* The vena portæ does not exist in the invertebrated animals, and yet, in a number of them, there is no hepatic apparatus, and a secretion of bile. *Thirdly.* Admitting that the vena portæ is distributed to the liver after the manner of an artery; is it clear, it has been asked, that it is inservient to the biliary secretion? *Fourthly.* If the vena portæ be more in proportion to the size of the liver than the hepatic artery, the latter appears to bear a better ratio to the quantity of bile secreted; and, *Lastly*, it is probable, as has been shown in another place, that the liver has other functions connected with the portal system, in the admixture of heterogeneous liquids absorbed from the intestinal canal.

In the absence of accurate knowledge, derived from direct experiment, physiologists have usually embraced one or the other of these exclusive views. The generality, as we have remarked, assign the function to the vena portæ. Bichat, on the other hand, ascribes it to the hepatic artery. Broussais thinks it probable, that the blood of the vena portæ is not foreign to the formation of the bile, since it is confounded with that of the hepatic artery in the parenchyma of the liver; "but to say with the older writers, that the bile cannot be formed but by venous blood, is, in our opinion," he remarks, "to advance too bold a position, since the hepatic artery sends branches to each of the glandular acini, that compose the liver." Magendie likewise concludes, that nothing militates against the idea of both kinds of blood serving in the secretion; and that it is supported by anatomy; as injections prove, that all the vessels of the liver,—arterial, venous, lymphatic, and excretory,—communicate with each other. Mr. Kiernan, as we have seen, considers, that the blood of the hepatic artery is inservient to the secretion, but not until it has become venous, and entered the portal veins. He, with all those that coincide with him, in the anatomical arrangement of these parts—denies that there is any communication between the ducts and the blood-vessels; and he asserts that if injections pass between them, it is owing to the rupture of the coats of the vessels. Experiments on pigeons, by M. Simon, of Metz, showed, that when the hepatic artery was tied, the secretion of bile continued, but that if the veins of the porta and the hepatic veins were tied, no trace of bile was subsequently found in the liver. It would thence appear, that in these animals, the secretion of bile takes place from venous blood; but inferences from the ligature of those vessels have been

very discordant. In two cases, in which Mr. Phillips tied the hepatic artery, the secretion of bile was uninterrupted: but the same thing was observed in three other cases, in which the ligature was applied to the trunk of the vena portæ.

The view, that ascribes the bile to the hepatic artery, appears to us the most probable. It has all analogy in its favour. We have no disputed origin as regards the other secretions. They all proceed from arterial blood; and function sufficient, we think, can be assigned to the portal system, without conceiving it to be concerned in the formation of bile. We have, moreover, pathological cases, which would seem to show that bile can be formed from the blood of the hepatic artery. Mr. Abernethy met with an instance, in which the trunk of the vena portæ terminated in the vena cava; yet bile was found in the biliary ducts. A similar case is given by Mr. Lawrence; and the present Professor Monro, in his "Elements of Anatomy," details a case communicated to him by the late Mr. Wilson, of the Windmill street school, in which there was reason to suppose, that the greater part of the bile had been derived from the hepatic artery. The patient, a female, thirteen years old, died from the effects of an injury of the head. On dissection, Mr. Wilson found a large swelling at the root of the mesentery, consisting of several absorbent glands in a scrofulous state. Upon cutting into the mass, he accidentally observed a large vein passing directly from it into the vena cava inferior, which, on dissection, proved to be the vena portæ; and on tracing the vessels entering into it, one was found to be the inferior mesenteric vein; and another, which came directly to meet it, from behind the stomach, proved to be a branch of the splenic vein, but somewhat larger, which ran upwards by the side of the vena cava inferior, and entered that vein immediately before it passes behind the liver. Mr. Wilson then traced the branches of the trunk of the vessel corresponding to the vena portæ sufficiently far in the mesentery and mesocolon, to be convinced, that it was the only vessel that returned the blood from the small intestines, and from the cæcum and colon of the large. He could trace no vein passing into the liver at the cavity of the porta; but a small vein descended from the little epiploon, and soon joined one of the larger branches of the splenic vein. The hepatic artery came off in a distinct trunk from the aorta, and ran directly to the liver. It was much larger than usual.

The greater size of the hepatic artery, in this case, would favour the idea, that the arterial blood had to execute some office, that ordinarily belongs to the vena portæ. Was this the formation of bile? The case seems, too, to show, that bile can be formed from the blood of the hepatic artery.

In Professor Hall's patient, the vena portæ and its bifurcation were completely filled with encephaloid matter, so that no blood could pass through it to the liver; the secretion of the bile could not, consequently, be effected through its agency. It has been presumed,

however, that, in such cases, portal blood might still enter the liver through the extensive anastomoses, which Professor Retzius, of Stockholm, found to exist between the abdominal veins. That gentleman observed, when he tied the vena portæ near the liver, and threw a coloured injection into the portion below the ligature, that branches were filled, some of which, proceeding from the duodenum, terminated in the vena cava; whilst others, arising from the colon, terminated in the left emulgent vein. In subsequent investigations, he observed an extensive plexus of minute veins ramifying in the cellular tissue on the outer surface of the peritoneum, part of which were connected with the vena portæ, whilst the other part terminated in the system of the vena cava. In a successful injection, these veins were seen anastomosing very freely, in the posterior part of the abdomen, with the colic veins, as well as with those of the kidneys, pelvis, and even with the vena cava.

The arrangement, pointed out by Retzius, accounts for the mode in which the blood of the abdominal venous system reaches the cava, when the vena porta is obliterated from any cause; and it shows the *possibility* of portal blood reaching the liver so as to be subservient to the biliary secretion, but does not, we think, exhibit its *probability.*

When bile is once secreted in the tissue of the liver, it is received into the minute excretory radicles, whence it proceeds along the ducts, until it arrives, from all quarters, at the hepatic duct.

A difference of sentiment exists regarding the flow of the bile from the liver and gall-bladder into the duodenum. According to some, it is constantly passing along the choledoch duct; but the quantity is not the same during digestion as at other times. In the intervals, a part only of the secreted bile attains the duodenum; the remainder ascends along the cystic duct, and is deposited in the gall-bladder. During digestion, however, not only the whole of the secretion arrives at the duodenum, but all that which has been collected in the interval is evacuated into the intestine. In support of this view it is affirmed, that bile is always met with in the duodenum; that the gall-bladder always contains more bile when abstinence is prolonged, whilst it is empty immediately after digestion.

The great difficulties have been, to explain how the bile gets into the gall-bladder, and how it is expelled from that reservoir. In many birds, reptiles, and fishes, the hepatic duct and the cystic duct open separately into the duodenum; whilst ducts, called *hepato-cystic*, pass directly from the liver to the gall-bladder. In man, however, the only visible route, by which it can reach that reservoir, is by the cystic duct, the direction of which is retrograde; and, consequently, the bile has to ascend against gravity. The spiral valve of Amussat has been presumed to act like the screw of Archimedes, and to facilitate the entrance of the refluent bile, but this appears to be imaginary. It is, indeed, impossible to see any analogy between the corporeal and the hydraulic instrument. The arrangement of the

termination of the choledoch duct in the duodenum has probably a more positive influence. The embouchure is the narrowest part of the duct, the ratio of its calibre to that of the hepatic duct having been estimated at not more than one to six, and to the calibre of its own duct as one to fifteen. This would render it impracticable for the bile to flow into the duodenum as promptly as it arrives at the embouchure; and, in this way, collecting in the duct, it might reflow into the gall-bladder. Amussat, indeed, affirms, that this can be demonstrated on the dead body. By injecting water or mercury into the upper part of the hepatic duct, the injected liquid was found to issue both by the aperture into the duodenum, and by the upper aperture of the cystic duct into the gall-bladder.

With regard to the mode in which the gall-bladder empties itself during digestion, it is probably by a contractile action. We have seen, that it has not usually been admitted to possess a muscular coat, but that it is manifestly contractile. The chyme, as it passes into the duodenum, excites the orifice of the choledoch duct this excitement is propagated along the ducts to the gall-bladder, which contracts; but, according to Amussat, it does not evacuate its contents suddenly, for the different planes of the spiral valve are applied against each other, and only permit the flow to take place slowly. This he found was the case, in the subject, when water was injected into the gall-bladder, and pressed out through the cystic duct.

Other physiologists have presumed, that although the bile is secreted in a continuous manner, it only flows into the duodenum at the time of chylification; at other times, the choledoch duct is contracted, so that the bile is compelled to reflow through the cystic duct into the gall-bladder; and it is only when the gall-bladder is filled, that it passes freely into the duodenum. Independently, however, of other objections to this view, vivisections have shown, that if the orifice of the choledoch duct be exposed, whatever may be the circumstances in which the animal is placed, the bile is seen issuing *guttatim* at the surface of the intestine.

The biliary secretion, which proceeds immediately from the liver,—hence called *hepatic bile*,—differs from that obtained from the gall-bladder, which is termed *cystic bile*. The latter possesses greater bitterness, is thicker, of a deeper colour, and is that which has been usually analyzed. It is of a yellowish-green colour, viscid, and slightly bitter. Its chymical properties have been frequently examined; yet much is still needed, before we can consider the analysis satisfactory. It has been examined by Boerhaave, Verheyen, Baglivi, Hartmann, Macbride, Ramsay, Gaubius, Cadet, Van Bochante, Poulletier de la Salle, Fourcroy, Macclurg, Thénard, Berzelius, Chevreul, Leuret and Lassaigne, Tiedemann and Gmelin, &c. &c.

Thénard's analysis of 1100 parts of human bile is as follows:—Water, 1000; albumen, 42; resinous matter, 41; yellow matter, 2

to 10; free soda, 5 or 6; phosphate, muriate, and sulphate of soda, phosphate of lime, and oxide of iron, 4 or 5. According to Chevallier, it contains also a quantity of picromel.

Berzelius calls in question the correctness of Thénard's analysis, and gives the following:—Water, 908.4; picromel, 80; albumen, 3.0; soda, 4.1; phosphate of lime, 0.1; common salt, 3.4; phosphate of soda, with some lime, 1.0.

The results of Dr. Davy's analysis of healthy bile were as follows:—Water, 86.0; resin of bile, 12.5; albumen, 1.5. Lastly, the few experiments, that were performed by Tiedemann and Gmelin on human bile, indicated the existence of cholesterine, resin, picromel, &c., and accorded greatly with the analysis of Thénard.

Cadet considered bile as a soap with a base of soda, mixed with sugar of milk,—a view, which Raspail considers to harmonize with observed facts. Every other substance met with in the bile, Raspail looks upon as accessary.

Hepatic and cystic bile do not appear to differ materially from each other, except in the greater concentration of the different elements in the latter. Leuret and Lassaigne found them to be alike in the dog. Orfila, however, affirms, that human hepatic bile does not contain picromel.

The great uses of the bile have been detailed under the head of digestion. It has been conceived to be a necessary depurative excretion; separating from the blood matters that would be injurious if retained. This last idea is probable; but our knowledge of the precise changes, produced in the mass of blood by it, are extremely limited. The view has been ingeniously contended for by MM. Tiedemann and Gmelin, who regard the function of the liver to be supplementary to that of the lungs—in other words, to remove carbon from the system. The arguments, adduced in favour of their position, are highly specious, and ingenious. The resin of the bile, they say, abounds most in herbivorous animals, whose food contains a great disproportion of carbon and hydrogen. The pulmonary and biliary apparatuses are in different tribes of animals, and even in different animals of the same species, in a state of antagonism to each other. The size of the liver, and the quantity of bile are not in proportion to the quantity of food and frequency of eating, but inversely proportionate to the size and perfection of the lungs. Thus, in warm-blooded animals, which have large lungs, and live always in the air, the liver, compared with the body, is proportionally less than in those that live partly in water. The liver is proportionally still larger in reptiles, which have lungs with large cells incapable of rapidly decarbonizing the blood,—and in fishes, which decarbonize the blood but slowly by the gills, and, above all, in molluscous animals, which effect the same change very slowly, either by gills, or by small imperfectly developed lungs. Again,—the quantity of venous blood, sent through the liver, increases as the pulmonary system becomes less perfect. In the mammalia, and in birds, the

vena portæ is formed by the veins of the stomach, intestines, spleen, and pancreas; in the tortoise, it receives also the veins of the hind legs, pelvis, tail,—and the vena azygos: in serpents, it receives the right renal, and all the intercostal veins, in fishes, the renal veins, and those of the tail and genital organs. Moreover, during the hybernation of certain of the mammalia, when respiration is suspended, and no food taken, the secretion of bile goes on. Another argument is deduced from the physiology of the fœtus, in which the liver is proportionally larger than in the adult, and in which the bile is secreted copiously, as appears from the great increase of the meconium during the latter months of utero-gestation. Their last argument is drawn from pathological facts. In pneumonia and phthisis, the secretion of bile, according to their observations, is increased, in diseases of the heart, the liver is enlarged; and in the morbus cæruleus, the liver retains its fœtal proportion. In hot climates, too, where, in consequence of the greater rarefaction of the air, respiration is less perfectly effected than in colder, a vicarious decarbonization of the blood is established by an increased flow of bile.

Lastly;—Mr. Voisin, considers the liver to be a secreting organ, the office of which is the depuration not only of the venous blood, but, as we have before shown, of the chyle.

If the excretion of the bile be prevented from any cause, we know that derangement is induced; but it is probable, that its agency in the production of disease is much overrated; and that, as Broussais has suggested, the source of many of the affections, termed *bilious*, is in the mucous membrane lining the stomach and intestines; which, owing to the heterogeneous matters constantly brought into contact with it, must be peculiarly liable to be morbidly affected. When irritation exists there, we can easily understand how the secretion from the liver may be consecutively modified; the excitement spreading directly along the biliary ducts to the secretory organ.

5. *Secretion of Urine.*

This is the most extensive secretion, accomplished by any of the glandular structures of the body, and is essentially depurative; its suppression giving rise to formidable evils. The apparatus consists of the *kidneys*, which secrete the fluid; the *ureters*, which convey the urine to the bladder; the *bladder* itself, which serves as a reservoir for the urine; and the *urethra*, which conveys the urine externally. These will require a distinct consideration.

The *kidneys* are two glands situated in the abdomen; one on each side of the spine, (Fig. 138, K, K,) in the posterior part of the lumbar region. They are without the cavity of the peritoneum, which covers them at the anterior part only, and are situated in the midst of a considerable mass of adipous cellular tissue. The right kidney is nearly an inch lower down than the left, owing

to the thick posterior margin of the right lobe of the liver pressing it downwards.

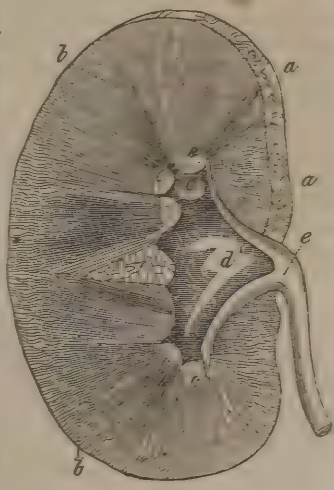
Occasionally, there is but one kidney; at other times, three have been met with.

They have the form of the *haricot* or *kidney-bean*, which has, indeed, been called after them; and are situated vertically—the fissure being turned inwards.

If we compare them with the liver, their size is by no means in proportion with the extensive secretion effected by them. Their united weight does not amount to more than six or eight ounces. They are hard, solid bodies, of a brown colour. The sanguiferous vessels, which convey and return the blood to them, as well as the excretory duct, communicate with the kidney at the fissure.

The anatomical constituents of these organs are;—1. The *renal artery* which arises from the abdominal aorta at a right angle, and, after a short course, enters the kidney; ramifying in its substance. 2. The *excretory ducts*, which arise from every part of the tissue, in which the ramifications of the renal artery terminate, and end in the *pelvis* of the kidney. (Fig. 139.) 3. The *renal veins*, which receive the superfluous blood, after the urine has been separated from it, and terminate in the *renal* or *emulgent vein*, which issues at the fissure, and opens into the abdominal vena cava. 4. Of lymphatic vessels, arranged in two planes—a superficial and deep-seated, which terminate in the lumbar glands. 5. Of *nerves*, which proceed from the semilunar ganglion, solar plexus, &c., and which surround the renal artery as with a net-work, following it in all its ramifications. 6. Of cellular membrane, which, as in every other organ, binds the parts together. These anatomical elements, by their union, constitute the organ as we find it.

Fig. 139.



Section of the Kidney.

a. a. The cortical substance.—*b. b.* The tubular portion.—*c. c. c. c.* The papillæ.—*d.* The pelvis: and *e.* The ureter.

When the kidney is divided longitudinally, it is seen to consist of two substances, which differ in their situation, colour, consistence and texture. The one of these, and the more external, is called the *cortical* or *glandular substance*. It forms the whole circumference of the kidney; is about two lines in thickness; of less consistence than the other; of a pale red colour; and receives almost entirely the ramifications of the renal artery. The other and innermost is the *tubular, medullary, uriniferous, conoidal* or *radiated substance*.

It is more dense than the other; less red; and seems to be formed of numerous minute tubes, which unite in conical bundles of unequal size, and the base of which is turned towards the cortical portion; the apices forming the *papillæ* or *mammillary processes*, and facing the pelvis of the kidney. The papillæ vary in number, from five to eighteen; are of a florid colour; and upon their points or apices are the terminations of the uriniferous tubes, large enough to be distinguished by the naked eye. Around the root of each papilla a membranous tube arises, called *calix* or *infundibulum:* this receives the urine from the papilla, and conveys it into the *pelvis* of the kidney, which may be regarded as the commencement of the ureter.

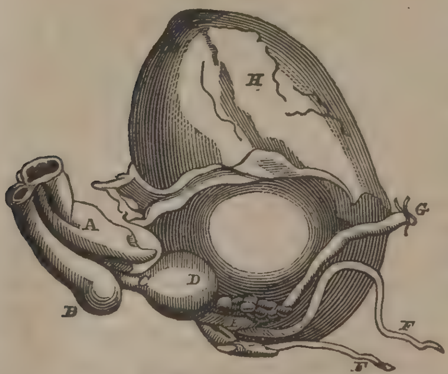
Similar ideas, with regard to the precise termination of the blood-vessel, and the commencement of the excretory duct, have prevailed as in the case of the liver and other glands: their intimate structure, however, escapes detection.

In the quadruped, each kidney is made up of numerous lobes, which are more or less intimately united, according to the species. In birds, the kidneys consist of a double row of distinct, but connected, glandular bodies, placed on both sides the lumbar vertebræ.

The *ureter* is a membranous duct, which extends from the kidney to the bladder. It is about the size of a goose-quill; descends through the lumbar region; dips into the pelvis by crossing in front of the primitive iliac vessels and the internal iliac; crosses the vas deferens at the back of the bladder, and, penetrating that viscus obliquely, terminates in an orifice, ten or twelve lines behind that of the neck of the bladder. At first, it penetrates two of the coats only of that viscus; running for the space of an inch between the mucous and muscular coats, and then entering the cavity.

The ureters have two coats. The outermost is a dense fibrous membrane; the innermost a thin mucous layer, continuous at its lower extremity with the inner coat of the bladder; and, at the upper end, supposed, by some, to be reflected over the papillæ, and even to pass for some distance into the tubuli uriniferi.

Fig. 140.



Bladder, Urethra, &c.

A. Crus penis.—B. Bulb of the urethra.—C. Membranous part of the urethra.—D. Prostate gland.—E. Vesiculæ seminales.—FF. Vasa deferentia.—G. Ureter.—H. Upper part of the bladder, covered by peritoneum.

The *bladder* is a musculo-membranous sac, situated in the pelvis; anterior to the rectum, and behind the pubis. Its superior end is called the *upper fundus;* and the lower end, the *inferior fundus* or *bas-fond;* the *body* being

situated between the two. The part where it joins the urethra is the *neck*. The shape and situation of the organ is influenced by age and by sex. In very young infants, it is cylindroid, and rises up almost wholly into the abdomen. In the adult female, who has borne many children, it is nearly spherical; has its greatest diameter transverse, and is more capacious than in the male.

Like the other hollow viscera, the bladder consists of several coats. 1. The *peritoneal* coat, which covers only the fundus and back part. Towards the lower portion the organ is invested by cellular membrane, which takes the place of the peritoneal coat of the fundus. This tissue is very loose, and permits the distention and contraction of the bladder. 2. The *muscular coat* is very strong; so much so, that it has been classed amongst the distinct muscles, under the name *detrusor urinæ*. The fibres are pale, and pass in various directions. Towards the lower part of the bladder, they are particularly strong; arranged in fasciculi, and form a kind of net-work, of muscles inclosing the bladder. In cases of stricture of the urethra, where much effort is necessary to expel the urine, these fasciculi acquire considerable thickness and strength. 3. The *mucous* or *villous coat* is the lining membrane, which is continuous with those of the ureters and urethra, and is generally rugous, in consequence of its being more extensive than the muscular coat without. It is furnished with numerous follicles, which secrete a fluid to lubricate it. Towards the neck of the organ, it is thin and white, though reddish in the rest of its extent.

A fourth coat, called the *cellular*, has been reckoned by most anatomists, but it is nothing more than cellular tissue uniting the mucous and muscular coats.

The part of the internal surface of the bladder, situated immediately behind and below its neck, and occupying the space between it and the orifices of the ureters, is called the *vesical triangle*, *trigonus Lieutaudi*, or *trigone vésical*. The anterior angle of the triangle looks into the orifice of the urethra, and is generally so prominent, that it has obtained the name of *uvula vesicæ*. It is merely a projection of the mucous membrane, dependent upon the subjacent third lobe of the prostate gland, which, in old people, is frequently enlarged, and occasions difficulty in passing the catheter.

The neck of the bladder penetrates the prostate gland, but, at its commencement, it is surrounded by loose cellular tissue, containing a very large and abundant plexus of veins. The internal layer of muscular fibres is here transverse; and they cross and intermix with each other, in different directions, forming a close, compact tissue, which has the effect of a particular apparatus for retaining the urine, and has been called the *sphincter*. Anatomists have not usually esteemed this structure to be distinct from the muscular coat at large; but Sir Charles Bell asserts, that if we begin the dissection by taking off the inner membrane of the bladder from around the orifice of the urethra, a set of fibres will be discovered,

on the lower half of the orifice, which, being carefully dissected, will be found to run in a semicircular form around the urethra. These fibres make a band of about half an inch in breadth, particularly strong on the lower part of the opening; and having ascended a little above the orifice, on each side, they dispose of a portion of their fibres in the substance of the bladder. A smaller and somewhat weaker set of fibres will be seen to complete their course, surrounding the orifice on the upper part.

The arteries of the bladder proceed from various sources, but chiefly from the umbilical and common pudic. The veins return the blood into the internal iliacs. They form a plexus of considerable size upon each side of the bladder, particularly about its neck.

The lymphatics accompany the principal veins of the bladder, and, at the under part and sides, pass into the iliac glands. The nerves are from the great sympathetic and sacral.

The *urethra* is the excretory duct of the bladder. It extends, in the male, from the neck of the bladder to the extremity of the glans; and is from seven to ten inches in length. In the female it is much shorter. The male urethra has several curvatures in the state of flaccidity of the penis; but is straight or nearly so, if the penis be drawn forwards and upwards, and if the rectum be empty.

The first portion of this canal, which traverses the prostate gland, is called the *prostatic portion*. Into it open,—on each side of a caruncle, called the *verumontanum*, *caput gallinaginis* or *crista urethralis*,—the two ejaculatory ducts, those of the prostate, and, a little lower, the orifice of Cowper's glands.

Between the prostate and the bulb is the *membranous part of the urethra*, which is eight or ten lines long. The remainder of the canal is called the *corpus spongiosum* or *spongy portion*, because surrounded by an erectile spongy tissue. It is situated beneath the corpora cavernosa, and passes forward to terminate in the *glans;* the structure of which will be considered under GENERATION.

At the commencement of this portion of the urethra is the *bulb* of the urethra, Fig. 140 B.; the structure of which resembles that of the corpora cavernosa of the penis—to be described hereafter.

The dimensions of the canal are various. At the neck of the bladder, it is considerable; behind the caput gallinaginis it contracts, and immediately enlarges in the forepart of the prostate. The membranous portion is narrower; and, in the bulb, the channel enlarges. In the body of the penis, it diminishes successively, till it nearly attains the glans, when it is so much increased in size as to have acquired the name *fossa navicularis*. At the apex of the glans it terminates by a short vertical slit.

Mr. Shaw has described a set of vessels, immediately on the outside of the internal membrane of the urethra; which, when empty, are very similar, in appearance, to muscular fibres. These vessels, he remarks, form an internal spongy body, which passes down to the membranous part of the urethra, and forms even a small bulb

there. Dr. Horner, however, says, that this appeared to him to be rather the cellular membrane connecting the canal of the urethra with the corpus spongiosum.

The whole of the urethra is lined by a very vascular and sensible mucous membrane, which is continued from the inner coat of the bladder. It has, apparently, a certain degree of contractility, and therefore, by some anatomists, is conceived to possess muscular fibres. Sir Everard Home, from the results of his microscopical observations, is disposed to be of this opinion. This is, however, so contrary to analogy, that it is probable the fibres may be seated in the tissue surrounding it.

The membrane contains numerous follicles, and several lacunæ, one or two of which, near the extremity of the penis, are so large as occasionally to obstruct the catheter, and to convey the impression that a stricture exists.

The prostate and the glands of Cowper, being more concerned in generation, will be described hereafter.

There are certain muscles of the perineum, that are engaged in the expulsion of the urine from the urethra; and some of them in defecation and in the evacuation of the sperm likewise; as the *acceleratores urinæ*, or *bulbo-urethrales*, which propel the urine or semen forward; the *transversus perinei*, or *ischio-perinealis*, which dilates the bulb for the reception of the urine or semen; the *sphincter ani*, which draws down the bulb, and thus aids in the ejection of the urine or sperm; and the *levator ani*, which surrounds the extremity of the rectum, the neck of the bladder, the membranous portion of the urethra, the prostate gland, and a part of the vesiculæ seminales, and assists in the evacuation of the bladder, vesiculæ seminales, and prostate. A part of the levator, which arises from the pubis and assists in inclosing the prostate gland, is called by Sömmering, *compressor prostatæ*.

Between the membranous part of the urethra, and that portion of the levator ani which arises from the inner side of the symphysis pubis, a reddish, cellular, and very vascular substance exists, which closely surrounds the canal, has been described by Mr. Wilson under the name *compressor urethræ*, and is termed, by some of the French anatomists, *muscle de Wilson*. By many, however, it is considered to be a part of the levator ani. Amussat asserts, that the membranous part of the urethra is formed, externally, of muscular fibres, which are susceptible of energetic contraction, and Magendie confirms his assertion.

With regard to the *urinary organs* of the *female*,—the kidneys and ureters have the same situation and structure as those of the male. The bladder, also, holds the same place behind the pubis, but rises higher when distended. It is proportionally larger than the bladder of the male, and is broader from side to side, thus allowing the greater retention to which females are often necessitated. The urethra is much shorter, being only about an inch and a half, or two

inches long, and it is straighter than in the male, having only a slight curve downwards between its extremities, and passing almost horizontally under the symphysis of the pubis. It has no prostate gland, but is furnished, as in the male, with follicles and lacunæ, which provide a mucus to lubricate it.

In birds in general, and in many reptiles and fishes, the urine, prior to expulsion, is mixed with the excrement in the cloaca. Nothing analogous to urinary organs has been detected in the lowest classes of animals, although in the dung of the caterpillars of certain insects, traces of urea have been met with.

The urine is separated from the blood in the kidneys. According to Raspail, it is a kind of *caput mortuum*, rejected into the urinary bladder by those glands. The proofs of this separation are easy and satisfactory; but with regard to the mode in which the operation is effected, we are in the same darkness that hangs over the glandular secretions in general. The transformation must, however, occur in the cortical part of the organ; for the tubular portion seems to consist only of a collection of excretory ducts, and, if we cut into it, urine oozes out.

The urinary secretion takes place continuously. If a catheter be left in the bladder, the urine drops constantly; and in cases of *exstrophia* of the bladder—a faulty conformation, in which the organ opens above the pubes, so that a red mucous surface, formed by the inner coat of the bladder, is seen in the hypogastric region, in which two prominences are visible, corresponding to the openings of the ureters—the urine is seen to be constantly passing out at these openings.

After the secretion has been effected in the cortical substance, it flows through the tubular portion, and issues *guttatim* through the apices of the papillæ into the pelvis of the kidney, whence it proceeds along the ureter to the bladder. When the uriniferous cones are slightly compressed, the urine issues in greater quantity, but, instead of being limpid, as when it flows naturally, it is thick and troubled. Hence a conclusion has been drawn, that it is really filtered through the hollow fibres of the medullary or tubular portion. If this were the case, what must become of the separated thick portion? Ought not the tubes to become clogged up with it? And is it not more probable, that compression, in this case, forces out with the urine some of the blood that is connected with the nutrition of the organ?

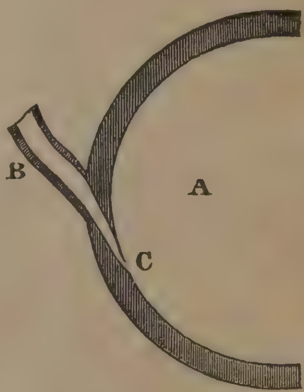
The fresh secretion constantly taking place in the kidney causes the urine to flow along the tubuli uriniferi to the pelvis of the organ, whence it proceeds along the ureter, if we are in the erect attitude, by virtue of its gravity; the fresh fluid, too, continually secreted from the kidney, pushes on that which is before it; and, moreover, there is not improbably some degree of contractile action exerted by the ureters themselves; although, as in the case of the excretory ducts in general, such a power has been denied them. These are the chief

causes of the progression of the urine into the bladder, which is aided by the pressure of the abdominal contents and muscles, and, it is supposed, by the pulsation of the renal and iliac arteries; but the agency of these must be trivial.

The orifices of the ureters form the posterior angles of the *trigone vésical*, and are contracted somewhat below the size of the ducts themselves. They are said, by Sir Charles Bell, to be furnished with a small fasciculus of muscular fibres, which runs backwards from the orifice of the urethra, immediately beneath the lateral margins of the triangle, and, when it contracts, stretches the orifice of the ureter so as to permit the urine to enter the bladder with facility.

As the urine enters, it gradually distends the organ until the quantity has attained a certain amount. It cannot reflow by the ureters, on account of the smallness of their orifices and their obliquity; and as the bladder becomes filled,—owing to the duct passing for some distance between the muscular and mucous coats,—the sides are pressed against each other, so that the cavity is obliterated. (Fig. 141.) Besides, when we are in the erect attitude, the urine would have to enter the ureters against gravity. These obstacles are so effective, that if an injection be thrown forcibly and copiously through the urethra into the bladder, it does not enter the ureters. On the other hand, equally powerful impediments exist to its being discharged through the urethra. The inferior fundus of the bladder is situated lower than the neck; and the sphincter presents a degree of resistance, which requires the bladder to contract forcibly on its contents, aided by the abdominal muscles to overcome it. Magendie considers the contraction of the levatores ani to be the most efficient cause of the retention of the urine; the fibres which pass around the urethra pressing its sides against each other and thus closing it.

Fig. 141.



Entrance of the ureter into the bladder.

A. Cavity of the bladder.—B. Ureter.—C. Vesical orifice of the ureter.

The urine accumulates in the bladder until the desire arises to expel it. During its stay in this reservoir, it is believed to be deprived of some of its more aqueous portions by absorption, and to become of greater specific gravity, and more coloured: it is here that those depositions are apt to take place which constitute *calculi;* although we meet with them in the kidneys and ureters also.

As in every excretion, a sensation first arises, in consequence of

which the muscles required for the ejection of the secreted matter are called into action. This sensation arises whenever the urine has accumulated to the necessary extent, or when it possesses irritating qualities, owing to extraneous substances being contained in, or deposited from, it; or if the bladder be unusually irritable from any morbid cause, the sensation may be repeatedly—nay, almost incessantly experienced. The remarks, that have been made on the sensations accompanying the other excretions, are equally applicable here. The impression takes place in the bladder; such impression is conveyed to the brain, which accomplishes the sensation; and, consecutively, the muscles, concerned in the excretion, are called into action by volition.

Physiologists have differed regarding the power of volition over the bladder. Some have affirmed, that it is as much under cerebral control as the muscles of locomotion; and they have adduced, in support of this view, that the bladder receives spinal nerves, which are voluntary; that it is paralyzed in affections of the spinal marrow, like the muscles of the limbs: and that a sensation, which seems destined to arouse the will, is always the precursor of its action.

Others, again, have denied, that the muscular fibres of the bladder are contractile under the will; and they adduce the case of other reservoirs,—the stomach and the rectum, for example,—whose influence in excretion we have seen to be involuntary; as well as the fact, that we no more feel the contraction of the bladder than we do that of the stomach or intestines; and they affirm, that the action of the bladder itself has been confounded with that of the accessory muscles, which are manifestly under the influence of the will, and are important agents in the expulsion of the fluid from the bladder.

The views, last expressed, appear to be most accurate, and the catenation of phenomena seems to be as follows:—the sensation to expel the urine arises; the abdominal muscles are thrown into contraction by volition; the viscera are thus pressed down upon the pelvis; the muscular coat of the bladder is, at the same time, stimulated to contraction; the levatores ani and the sphincter fibres are relaxed, so that the resistance of the neck of the organ is diminished, and the urine is forced out through the whole extent of the urethra, being aided in its course, especially towards the termination, by the contractile action of the urethra itself, as well as by the levatores ani and acceleratores urinæ muscles. These expel the last drops by giving a slight succussion to the organ, and directing it upwards and forwards; an effect which is aided by shaking the organ to free it from the drops that may exist in the part of the canal near its extremity. The gradually diminishing jet, which we notice, as the bladder is becoming empty, indicates the contraction of the muscular coat of the organ; whilst the kind of intermittent jet, coincident with voluntary muscular exertion, indicates the contraction

of the urethral muscles. When we feel the inclination to evacuate the bladder, and do not wish to obey it, the same muscles,—the levatores ani, the acceleratores urinæ, and the fibres around the membranous portion of the urethra and the neck of the bladder—are thrown into contraction, and resist that of the bladder.

Such is the ordinary mechanism of the excretion of urine. The contraction of the bladder is, however, of itself sufficient to expel its contents. Magendie affirms, that he has frequently seen dogs pass urine when the abdomen was opened, and the bladder removed from the influence of the abdominal muscles; and he farther states, that if, in a male dog, the bladder, with the prostate and a small portion of the membranous part of the urethra, be removed from the body, the bladder will contract after a few moments, and project the urine, with an evident jet, until it is entirely expelled.

Urine—voided in the morning by a person who has eaten heartily, and taken no more fluid than sufficient to allay thirst—is a transparent, limpid fluid, of an amber colour, saline taste, and a peculiar odour. Its specific gravity is a little above that of water, or 1.030. It is slightly acid, for it reddens vegetable blues. Although at first quite transparent, it deposits an insoluble matter on standing; so that urine, passed at bed-time, is found to have a light cloud floating in it by the following morning. This substance consists, in part, of mucus from the urinary passages; and, in part, of the super-urate of ammonia, which is much more soluble in warm than in cold water.

The urine is extremely prone to decomposition. When kept for a few days, it acquires a strong smell, which, being *sui generis*, has been called *urinous;* and as the decomposition proceeds, the odour becomes extremely disagreeable. The urine, as soon as these changes commence, ceases to have an acid reaction, and the earthy phosphates are deposited. In a short time, a free alkali makes its appearance; and a large quantity of the carbonate of ammonia is generated. These phenomena are owing to the decomposition of urea, which is almost wholly resolved into carbonate of ammonia.

Dr. Henry affirms, that the following substances have been satisfactorily proved to exist in healthy urine,—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatine, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluate of lime, muriate of soda, phosphate of soda, phosphate of ammonia, sulphur, and silex.

The most recent and elaborate analysis has been given by Berzelius. He states it to consist—in 1000 parts, of water, 933.00; urea, 30.10; sulphate of potassa, 3.71; sulphate of soda, 3.16; phosphate of soda, 2.94; muriate of soda, 4.45; phosphate of ammonia, 1.65; muriate of ammonia, 1.50; free lactic acid, lactate of ammonia, animal matter, soluble in alcohol, and urea not separable from the

preceding, 17.14; earthy phosphates, with a trace of fluate of lime, 1.00; lithic acid, 1.00; mucus of the bladder, 0.32; silex, 0.03.

M. Raspail thinks it 'possible' that uric acid is merely a mixture of organic matter (albumen) with an acid cyanide of mercury; so that the results of analysis may differ according as the analyzed substance may have been more or less separated from the organic matter. The physical and chymical characters of uric acid, he thinks, accord very well with this hypothesis.

The yellowish-red incrustation, deposited on the sides of chamber utensils, is the uric acid. This is the basis of one of the varieties of calculi.

The quantity of urine, passed in the twenty-four hours, is very variable. On the average, it is estimated at two pounds, or two pounds and a half; hence the cause of the great size of the renal artery, which, according to the estimate of Haller, conveys to the kidney a sixth or eighth part of the whole blood. Its quantity and character vary according to age, and, to a certain extent, according to sex. We have already seen, under the head of *cutaneous exhalation*, how it varies, according to climate and season; and it is influenced by the serous, pulmonary, and cellular exhalations likewise: one of the almost invariable concomitants of dropsy is diminution of the renal secretion. Its character, too, is modified by the nature of the substances received into the blood. Rhubarb, turpentine, and asparagus materially alter its physical properties; whilst certain articles stimulate the kidney to augmented secretion, or are *diuretics.*

The urine does not appear to be intended for any local function. Its use seems to be restricted to the removal of the elements of the substances, of which it is composed, from the blood; hence it is solely depuratory and decomposing.

How this decomposition is accomplished, we know not. We have already referred to the experiments, performed by MM. Prévost and Dumas, Ségalas, Gmelin, Tiedemann and Mitscherlich, in which urea was found in the blood of animals whose kidneys had been extirpated; an inquiry has consequently arisen,—how it exists there? Prior to these experiments, it was universally believed, that its formation is one of the mysterious functions executed in the intimate tissue of the kidney.

Urea, which, according to Wöhler, is a cyanide of ammonia, contains a very large proportion of azote, so that it has been imagined, the kidney may possibly be the outlet for an excess of azote, or for preventing its accumulation in the system,—in the same manner as the lungs and liver have been regarded as the outlets for the superfluous carbon.

The quantity of azote, discharged in the form of urea, is so great, even in those animals, whose food does not essentially contain this element, that it has been conceived a necessary ingredient in the nutrition of parts, and especially in the formation of fibrine, which,

we have seen, is a chief constituent of the blood, and of every muscular organ. The remarks, made on the absorption of azote during respiration, indicate how it is received into the system; and it has been presumed, that the superfluous portion is thrown off in the form of urea.

The experiments of MM. Prévost and Dumas, and of the other physiologists, would certainly favour the conclusion, that urea may exist ready formed in the blood, and that the great function of the kidney may be to separate it along with the other constituents of the urine.

Adelon ascribes the source of the urea to the products of interstitial decomposition. He conceives, that, in this shape, they are received into the blood, and that the office of the kidneys is to separate them. All this is necessarily conjectural: it must be admitted that our knowledge of the subject is by no means ample, and that we must wait for farther developements.

Certain it is, that the removal of the constituents of the urinary secretion from the blood is all-important. Experiments on animals have shown, that if it be suppressed by any cause for about three days, death usually supervenes, and the dangers to man are equally imminent. Yet there are some strange cases of protracted suppression on record. Haller mentions a case, in which no urine had been secreted for 22 weeks; and Dr. Richardson one of a lad of 17, who had never made any, and yet felt no inconvenience.

In consequence of the rapidity with which fluids, received into the stomach, are sometimes voided by the urinary organs, it has been imagined, either that vessels exist, which communicate directly between the stomach and bladder, or that the fluid passes through the intermediate cellular tissue, or by means of the anastomoses of the lymphatics.

In support of the opinion, that a more direct passage exists, the assertion of Chirac,—that he saw the urinary bladder become filled with urine, when the ureters were tied, and that he excited urinous vomiting, by tying the renal arteries, is adduced. It has been farther affirmed, that the oil, composing a glyster, has been found in the bladder. Darwin, having administered to a friend a few grains of nitrate of potassa, collected his urine at the expiration of half an hour, and had him bled. The salt was detected in the urine, but not in the blood. Brande made similar experiments with the prussiate of potassa, from which he inferred, that the circulation is not the only medium of communication between the stomach and the urinary organs, without, however, indicating the nature of the supposed medium; and this view is embraced by Sir Everard Home, Wollaston, Marcet, and others. Very recently, Lippi, of Florence, thinks he has found an anatomical explanation of the fact. According to him, the chyliferous vessels have not only numerous inosculations with the mesenteric veins, either before their entrance into the me-

senteric glands, or whilst they traverse the glands; but, when they attain the last of those glands, some of them proceed to open directly into the renal veins, and into the pelves of the kidneys. At this place, according to him, the chyliferous vessels divide into two sets; the one, ascending and conveying the chyle into the thoracic duct; the other, descending and carrying the drinks into the renal veins and pelves of the kidneys. He affirms, that the distinction between these two sets is so marked, that an injection, sent into the former, goes exclusively into the thoracic duct, whilst if it be thrown into the latter it passes exclusively to the kidneys. These direct vessels Lippi calls *vasa chylopoietica urinifera.*

If the assertions of Lippi were anatomical facts, it would obviously be difficult to doubt some of the deductions; other anatomists have not, however, been so fortunate as he; and, consequently, it may be well to make a few comments.

Some of these chylopoietica urinifera, he affirms, open into the renal veins. This arrangement, it is obvious, cannot be invoked to account for the shorter route,—the *royal road* to the kidney: the renal vessel is conveying the blood back *from* the kidney, and everything, that reaches it from the intestines, must necessarily pass into the vena cava, and ultimately attain the kidney through the renal artery. The vessels, therefore, that end in the renal veins, must be put entirely out of the question, so far as regards the topic of dispute; and our attention be concentrated upon those that terminate in the pelvis of the kidney. Were this termination proved, we should be compelled, as we have remarked, to bow to authority; but not having been so, it may be stated as seemingly improbable, that the ducts in question should take the circuitous course to the pelvis of the kidney, instead of proceeding directly to the bladder.

We know, then, anatomically, nothing of any canal existing between the stomach and the bladder; and we have not the slightest evidence,—positive or relative,—in favour of the opinion, that there is any transmission of fluid through the intermediate cellular tissue. We have, indeed, absolute testimony against it. MM. Tiedemann and Gmelin, having examined the lymphatics and cellular tissue of the abdomen, in cases where they had administered indigo and essence of turpentine to animals, discovered no traces whatever of them, whilst they could be detected in the kidney.

The *facts*, again, referred to by Chirac, are doubtful. If the renal arteries be tied, the secretion cannot be effected by the kidney; yet, as we have seen, in the case of the extirpated kidneys, urea may exist in the blood, and, consequently, urinous vomitings be possible. If the ureters be tied, the secretion being practicable, death will occur if the suppression be protracted; and, in such case, the secreted fluid may pass into the vessels, and readily give a urinous character to the perspiration, vomited matters, &c. &c.

Again, the experiments of Darwin, Brande, Wollaston, and others only demonstrate, that these gentlemen were unable to detect that in

the blood which they found in the urine. Against the *negative* results attained by these gentlemen, we may adduce the positive testimony of Fodéra, an experimentalist of weight, especially on those matters. He introduced into the bladder of a rabbit a plugged catheter, and tied the penis upon the instrument to prevent the urine from flowing along its sides. He then injected into the stomach a solution of the ferrocyanate of potassa. This being done, he frequently removed the plug of the catheter, and received the drops of urine on filtering paper: as soon as indications of the presence of the salt appeared in the urine by the appropriate tests,—which usually required from five to ten minutes after its reception into the stomach,—the animal was killed; and, on examining the blood, the salt was found in the serum taken from the thoracic portion of the vena cava inferior, in the right and left cavities of the heart, in the aorta, the thoracic duct, the mesenteric glands, the kidneys, the joints, and in the mucous membrane of the bronchi.

Magendie, too, states, as the result of his experiments,—*First.* That whenever prussiate of potassa is injected into the veins, or is exposed to absorption in the intestinal canal, or in a serous cavity, it speedily passes into the bladder, where it can be readily recognized in the urine. *Secondly.* That if the quantity of prussiate injected be considerable, it can be detected in the blood by reagents; but if the quantity be small, it is impossible to discover it by the ordinary means. *Thirdly.* That the same thing happens if the prussiate of potassa be mixed with the blood out of the body. *Fourthly.* That the salt can be detected, in every proportion, in the urine.

The existence, consequently, of any more direct route from the stomach to the bladder than through the venous system is disproved, and the absorption of fluids must be considered to be effected through the vessels described under the *absorption of drinks.*

Such are the glandular secretions, which we shall consider in this place. There are still two important fluids, whose uses will have to be detailed in the next class of functions—the *sperm* and the *milk.* There are several organs likewise,—as the spleen, thyroid, thymus and supra-renal capsules,—which are termed glands by many anatomists; but which Chaussier has termed *glandiform ganglions.* Of the uses of these we know little or nothing. Yet it is necessary, that the nature of the organs, and their fancied functions should meet with notice. The offices of the thyroid, thymus, and supra-renal capsules,—being apparently confined to fœtal existence, —will not require consideration here.

OF THE FUNCTIONS OF THE SPLEEN.

The *spleen* is a viscus of considerable size, situated in the left hypochondriac region, (Fig. 138, H,) beneath the diaphragm, above the left kidney, and to the left of the stomach. Its medium length

is about four and a half inches; its thickness two and a half inches; and its weight about eight ounces. It is of a soft texture, somewhat spongy to the feel, and easily torn. In a very recent subject, it is of a grayish-blue colour; which, in a few hours, changes to a purple, so that it resembles a mass of clotted blood.

At its inner surface, or that which faces the stomach and kidney, a fissure exists, by which the vessels, nerves, &c. enter or issue from the organ.

The anatomical elements of the spleen are:—1. The *splenic artery*, which arises from the cœliac, and after having given off branches to the pancreas and the left gastro-epiploic artery, divides into several branches, which enter the spleen at the fissure, and ramify in the tissue of the organ, so that it seems to be exclusively formed by them. (Fig. 113.) Whilst the branches of the artery are still in the duplicature of the gastro-splenic omentum, and before they ramify in the spleen, they furnish the vasa brevia to the stomach. The precise mode of termination of the arteries in the spleen is unknown. The communication of the arteries with the veins does not, however, appear to be as free as in other parts of the body, or the anastomoses between the minute arteries as numerous.

If, according to Assolant, one of the branches of the splenic artery be tied, the portion of the spleen to which it is distributed, dies; and if air be injected into one of these branches, it does not pass into the others; so that the spleen would appear to be a congeries of several distinct lobes; and in certain animals the lobes are so separated as to constitute several spleens. A similar appearance is occasionally seen in the human subject. 2. The *splenic vein* arises by numerous radicles in the tissue of the spleen: these become gradually larger and less numerous, and leave the fissure of the spleen by three or four trunks, which ultimately, with veins from the stomach and pancreas, unite to form one, that opens into the vena portæ. It is without valves, and its parietes are thin. These are the chief constituents. 3. *Lymphatic vessels*, which are large and numerous. 4. *Nerves*, proceeding from the cœliac plexus: they creep along the coats of the splenic artery,—upon which they form an intricate plexus,—into the substance of the spleen. 5. *Cellular tissue*, which serves as a bond of union between these various parts; but is in extremely small quantity. 6. A *proper membrane*, which envelopes the organ externally; adheres closely to it, and furnishes fibrous sheaths to the ramifications of the artery and vein: keeping the ramifications separated from the tissue of the organ, and sending prolongations into the parenchyma, which give it more of a reticulated than spongy aspect. 7. Of *blood*, according to many anatomists, but blood differing from that of both the splenic artery and vein; containing, according to Vauquelin, less colouring matter and fibrine, and more albumen and gelatine, than any other kind of blood. This, by stagnating in the organ, is conceived to form an integrant part of it. Malpighi believed it

to be contained in cells; but others have supposed it to be situated in a capillary system intermediate to the splenic artery and vein.

Assolant and Meckel believe, that the blood is in a peculiar state of combination and of intimate union with the other organic elements of the viscus, and with a large quantity of albumen; and that this combination of the blood forms the dark brown pulpy substance, contained in the cells formed by the proper coat, and which can be easily demonstrated by tearing or cutting the spleen, and scraping it with the handle of a knife. These cells and the character of the tissue of the spleen are exhibited in the marginal figure. In addition to the pulp, many anatomists assert, that they have met with an abundance of rounded corpuscles, varying in size from an almost imperceptible magnitude to a line or more in diameter. By Malpighi, these were conceived to be granular corpuscles, and, by Ruysch, simply convoluted vessels.

Fig. 142.

Section of the spleen.

Besides the proper membrane, the spleen also receives a peritoneal coat; and, between the stomach and the organ, the peritoneum forms the *gastro-splenic epiploon* or *gastro-splenic ligament*, in the duplicature of which are situated the vasa brevia.

Lastly; the spleen is capable of distention and contraction; and is possessed of little sensibility in the healthy state. It has no excretory duct.

The hypotheses, which have been indulged on the nature of the spleen, are beyond measure numerous and visionary; and, after all, we are in the greatest obscurity as to its real uses.

Many of these hypotheses are too idle to merit notice; such are those, that consider it to be the seat of the soul,—the organ of dreaming,—of melancholy and of laughter,—of sleep and the venereal appetite,—the organ that secretes the mucilaginous fluids of the joints, that serves as a warm fomentation to the stomach, and so on.

It was long regarded as a secretory apparatus, for the formation of the atrabilis,—of a fluid intended to nourish the nerves,—of the gastric juice,—of a humour intended to temper the alkaline character of the chyle or bile, &c.

The absence of an excretory duct would be a sufficient answer to all these speculations, if the non-existence of these supposititious humours were insufficient to exhibit their absurdity.

MM. Tiedemann and Gmelin consider its function to be iden-

tical with that of the mesenteric glands. They regard it as a ganglion of the absorbent system, which prepares a fluid to be mixed with the chyle and effect its animalization. In favour of the view, that it is a part of the lymphatic system, they remark, that it exists only in those animals that have a distinct absorbent system; that its bulk is in a ratio with the developement of the absorbent system; that the lymphatics predominate in the structure of the organ; that its texture is like that of the lymphatic ganglions; and lastly, that, on dissecting a turtle, they distinctly saw all the lymphatics of the abdomen passing first to the spleen, then leaving that organ of larger size, and proceeding to the thoracic duct.

In support of their second position, that it furnishes some material towards the animalization of the chyle, they adduce;—the large size of the splenic artery, which manifestly, they conceive, carries more blood to the spleen than is needed for its nutrition; and they affirm, that, in their experiments, they have frequently found, whilst digestion and chylosis were going on, the lymphatic vessels of the spleen gorged with a reddish fluid, which was carried by them into the thoracic duct, where the chyle always has the most rosy hue; and they add, that a substance injected into the splenic artery, passes readily into the lymphatics of the spleen. Lastly, after extirpating the spleen in animals, the chyle appeared to them to be more transparent; no longer depositing coagula; and the lymphatic ganglions of the abdomen seemed to have augmented in size. Views, similar to these, have been maintained by Sir Everard Home.

Chaussier, as we have seen, classes the spleen amongst the *glandiform ganglions*, and affirms, that a fluid is exhaled into its interior of a serous or sanguineous character, which, when absorbed, assists in lymphosis.

Many, again, have believed, that the spleen is a sanguineous, not a lymphatic ganglion, but they have differed regarding the blood on which it exerts its action; some maintaining, that it prepares the blood for the secretion of the gastric juice; others for that of the bile. The former of these views is at once repelled by the fact, that the vessels, which pass from the splenic artery to the stomach, leave that vessel before it enters the spleen.

The latter has been urged, of late, by M. Voisin. He thinks, the principal use of the spleen is to furnish to the liver, blood containing those materials that enter into the composition of the bile; but this view, also, rests on very uncertain data and deductions.

Since the period of Haller, the blood of the splenic vein has been presumed to differ essentially from that of other veins, which has led to the belief, that some elaboration is effected in the spleen so as to fit the blood for the secretion of the bile. It has been described as more aqueous, more albuminous, more unctuous, and blacker than other venous blood; to be less coagulable, less rich in fibrine, and the fibrine it does contain to be less animalized. Yet these affirmations have been denied; and even were they admitted, we have no

positive knowledge, that such changes better adapt it for the formation of bile by the liver.

The ideas that have existed, regarding its acting as a diverticulum for the blood, have been mentioned under the head of CIRCULATION. By some, it has been supposed to act as such in the intervals of digestion; or, in other words, to be a diverticulum to the stomach; by others, its agency in this way is believed to apply to the whole circulatory system, so that when the flow of blood is impeded or arrested in other parts, it may be received into the spleen. Such a view was entertained by Dr. Rush. It is hard to say, which of these speculations is the most ingenious. None can satisfy the judicious physiologist, especially when he considers the comparative impunity consequent on extirpation of the organ.

This was an operation performed at an early period. Pliny affirms, that it was practised on runners to render them more swift. From animals the spleen has been repeatedly removed, and although many of these have died in consequence of the operation, several have recovered.

Adelon refers to the case of a man who was wounded by a knife under the last false rib of the left side. Surgical attendance was not had until twelve hours afterwards; and, as the spleen had issued at the wound, and was much altered, it was considered necessary to extirpate it. The vessels were tied; the man got well in less than two months, and has ever since enjoyed good health.

Sir Charles Bell asserts, in his 'Anatomy and Physiology,' that an old pupil had given him an account of his having cut off the spleen in a native of South America. The spleen had escaped through a wound, and had become gangrenous. He could observe no effect to result from the extirpation.

Dr. O'Brien, in an inaugural dissertation, published at Edinburgh, in 1818, refers to a case, which fell under his own management. The man was a native of Mexico: the spleen lay out, owing to a wound of the abdomen, for two days before the surgeon was applied to. The bleeding was profuse: the vessels and other connexions were secured by ligature, and the spleen separated completely on the twentieth day of the wound. On the forty-fifth day, the man was discharged from the hospital, cured; and he remarked to some one about this time, that "he felt as well as ever he did in his life."

Dulaurens, Kerckring, Baillie, and others, refer, also, to cases, in which the spleen has been found wanting in man, without any apparent impediment to the functions.

The experiments, that have been made on animals by removing the spleen, have led to discordant results. Malpighi says, that the operation was followed by increased secretion of urine; Dumas, that the animals had afterwards a voracious appetite; Mead, and Mayer, that digestion was impaired, that the evacuations were more liquid, and the bile more watery; Tiedemann and Gmelin, that the

chyle appeared more transparent and devoid of clot; Professor Coleman, that the dogs,—the subjects of the experiment,—were fat and indolent. A dog, whose spleen was removed by Mr. Mayo, became on recovering from the wound, fatter than before: in a year's time it had returned to its former condition, and no difference was observed in its appearance or habits from those of other dogs.

Dupuytren extirpated the spleens of forty dogs on the same day, without tying any vessel, but merely stitching up the wound of the abdomen,—yet no hemorrhage supervened. In the first eight days, half the dogs, operated on, died of inflammation of the abdominal viscera induced by the operation, as was proved by dissection. The other twenty got well without any accident at the end of three weeks at the farthest. At first, they manifested a voracious appetite, but it soon resumed its natural standard. They fed on the same aliment, the same drinks, took the same quantity of food, and digestion seemed to be accomplished in the same time. The fæces had the same consistence, the same appearance, and the chyle appeared to have the same character. Nor did the other functions offer any modification.

Dupuytren opened several of these dogs some time afterwards, and found no apparent change in the abdominal circulation,—in that of the stomach, epiploon, or liver. The last organ, which appeared to some of the experimenters to be enlarged, did not seem to him to be at all so. The bile alone appeared a little thicker, and deposited a slight sediment.

These circumstances render it extremely difficult to arrive at any theory regarding the offices of this anomalous organ. It is manifestly not essential to life, and therefore not probably inservient to the purposes assigned to it by Tiedemann and Gmelin. Bostock properly remarks, that its office must be something of a supplementary or vicarious nature; and this would accord best, perhaps, with the notion of its serving as a diverticulum; the blood speedily passing, after the organ has been extirpated, into other channels. It must be admitted, however, that our knowledge of the function is of a singularly negative and unsatisfactory character, and this is strikingly exemplified by the suggestion of Paley—certainly not predisposed to arrive at such a conclusion—that the spleen "may be merely a stuffing, a soft cushion to fill up a vacuum or hollow, which, unless occupied, would leave the package loose and unsteady."

CLASS III.

FUNCTIONS OF REPRODUCTION, OR GENERATION.

The functions, which we have been hitherto considering, relate exclusively to the individual. We have now to investigate those that refer to the preservation of the species, and without which living beings would soon cease to exist. Although these functions are really multiple, it has been the custom with physiologists to refer them to one head—*generation*—of which they are made to form the subordinate divisions.

The function of generation, much as it varies amongst organized bodies, is possessed by them exclusively. When a mineral gives rise to another of a similar character, it is at the expense of its own existence; whilst the animal and the vegetable produce being after being, without any curtailment of theirs.

The writers of antiquity considered that all organized bodies are produced in one of two ways. Amongst the upper classes of both animals and vegetables they believed the work of reproduction to be effected by a process, which is termed *univocal* or *regular generation*, (*generatio homogenea, propagatio;*) but in the very lowest classes, as the mushroom, the worm, the frog, &c. they conceived that the putrefaction of different bodies, aided by the influence of the sun, might generate life. This has been termed *equivocal* or *spontaneous generation*, (*generatio heterogenea, æquivoca, primitiva, primigena, originaria, spontanea;*) and is supposed to have been devised by the Egyptians to account for the swarms of frogs and flies, which appeared on the banks of the Nile after its periodical inundations.

Amongst the ancients, the latter hypothesis was almost universally credited. Pliny unhesitatingly expresses his belief, that the rat and the frog are produced in this manner; and, at his time, it was generally thought, that the bee, for example, was derived at times from a parent, but at others from putrid beef.*

The passage of Virgil,—in which he describes how the shepherd Aristæus succeeded in producing swarms of bees from the entrails of a steer, exposed for nine days to putrefaction,—is probably familiar to most readers, and exhibits the same belief.

The hypothesis of equivocal generation having been conceived, in consequence of the impracticability of tracing ocularly the function in the minute tribes of animals, it naturally maintained its ground, uninterruptedly, as regarded those animals, until better means of observation were invented. The difficulty, too, of admitting regular generation as applicable to all animals, was augmented by the fact,

* "Apes nascuntur partim ex apibus, partim ex bubulo corpore putrefacto."—Varro.

not at first known to naturalists, that many of the lower tribes conceal their eggs, in order that their nascent larvæ may find suitable food; but the existence of evident sexual organs in many of these small species induced physiologists, at an early period, to believe, that they also might be reproduced by sexual intercourse; direct proofs were not, however, obtained until the discovery of the microscope; after which the investigations of Redi, Vallisnieri, Swammerdam, Hooke, Réaumur, Bonnet and others clearly demonstrated, that many of the smallest insects have eggs and sexes, and that they reproduce like other animals.

In the case of plants, it has been supposed that the growth of the fungi amongst dung, and of the various parasitical plants that appear on putrid flesh, fruit, &c. furnishes facts in support of the equivocal theory; but the microscope exhibits the seeds of many of these plants, and experiments show that they are prolific. The characters, by which the different species and varieties are distinguished, although astonishingly minute, are fixed; exhibiting no fluctuation, such as might be anticipated did these plants arise by spontaneous generation, or by the fortuitous concourse of atoms.

The animalcules, that make their appearance in water in which vegetable or animal substances have been infused or are contained, would seem, at first sight, to favour the ancient doctrine. In these cases, however, the species, again, have determinate characters; presenting always the same proportion of parts; and appearing to transmit their vitality to their descendants in a manner not unlike that of animals and vegetables higher in the scale. The explanation, offered by the supporters of the univocal theory for those obscure cases in which direct observation fails us, is, that their seeds and eggs are so extremely minute, that they can be borne about by the winds, or by birds; be readily deposited, and, when they find a soil or nidus, favourable to their growth, can undergo developement. Thus, the soil, in which alone the *monilia glauca* flourishes, is putrid fruit; whilst the small infusory animal—the *vibrio aceti* or vinegar eel,—requires, for its growth, vinegar that has been for some time exposed to the air. "That the atmosphere," says Dr. Good, "is freighted with myriads of insect eggs, that elude our senses; and that such eggs, when they meet with a proper bed, are hatched in a few hours into a perfect form, is clear to any one who has attended to the rapid and wonderful effects of what, in common language, is called a *blight*, upon plantations and gardens. I have seen, as probably many, who may read this work, have also, a hop-ground completely overrun and desolated by the *aphis humuli* or *hopgreen-louse*, within twelve hours after a *honey-dew*, (which is a peculiar haze or mist, loaded with a poisonous miasm,) has slowly swept through the plantation, and stimulated the leaves of the hop to the morbid secretion of a saccharine and viscid juice, which, while it destroys the young shoots by exhaustion, renders them a favourite resort for this insect, and a cherishing nidus for the myriads of little dots that are

its eggs. The latter are hatched within eight-and-forty hours after their deposit, and succeeded by hosts of other eggs of the same kind; or, if the blight takes place in an early part of the autumn, by hosts of the young insects produced viviparously; for in different seasons of the year, the aphis breeds both ways.

"Now it is highly probable, that there are minute eggs or ovula of innumerable kinds of animalcules floating in myriads of myriads through the atmosphere, so diminutive as to bear no larger proportion to the eggs of the aphis than these bear to those of the wren, or the hedge-sparrow; protected, at the same time, from destruction by the filmy integument that surrounds them, till they can meet with a proper nest for their reception, and a proper stimulating power to quicken them into life; and which, with respect to many of them, are only found obvious to the senses in different descriptions of animal fluids.

"The same fact occurs in the mineral kingdom: stagnant water, though purified by distillation and confined in a marble basin, will, in a short time, become loaded on its surface or about its sides with various species of confervas; while the interior will be peopled with microscopic animalcules. So, while damp cellars are covered with boletuses, agarics and other funguses, the driest brick walls are often lined with lichens and mosses. We see nothing of the animal and vegetable eggs or seeds by which all this is effected; but we know, that they exist in the atmosphere, and that this is the medium of their circulation."

This view of the extraneous origin of the seeds of the confervas, &c. is corroborated by an experiment of Sénébier. He filled a bottle with distilled water, and corked it accurately: not an atom of green matter was produced, although it was exposed to the light of the sun for four years; nor did the green matter, considered as the first stage of spontaneous organization, exhibit itself in a glass of common water, covered with a stratum of oil.

It is proper, however, to remark, that the experiments of others invalidate the results of this. Burdach, in the presence of Professor Von Baer, poured water on marble in a glass vessel, the remainder of the vessel being filled with atmospheric air, oxygen or hydrogen, and placed it in the light of the sun, or in warm sand. No green matter was perceptible, but there was a slimy substance with white threads, part of which had a ramified appearance, and part that of coral. On the other hand, pieces of granite, newly broken from the midst of a block, produced—with fresh distilled water, and oxygen or hydrogen, in the sun—green matter, with threads of the confervas; but in the warmth of digestion flocculi only. He next took some mould, which he dug up, and which was inodorous, and apparently free from all foreign matter; boiled it in a considerable quantity of water, and reduced the decoction to the consistence of a thick, partly pulverulent extract. This gave, with common water and atmospheric air—in bottles with ground stoppers, tied over with bladder—

in the sun, numerous infusory animalcules and green matter; but with distilled water and oxygen or hydrogen, green matter only appeared at the bottom of the bottles.

The subject of intestinal worms has been eagerly embraced by the supporters of the doctrine of equivocal generation, who are of opinion, that the germs need not be received from without; whilst the followers of the univocal doctrine maintain, that they must always be admitted into the system.

The first opinion includes amongst its supporters the names of Needham, Buffon, Patrin, Treviranus, Rudolphi, Bremser, Himly, and other distinguished helminthologists. The latter comprises those who believe in the Harveian maxim,—*omne vivum ex ovo.*

To support the latter opinion, it has been attempted to show, that the worms, found in the human intestines, are precisely the same as others that have been found out of the body; but the evidence, in favour of this position, is by no means strong or satisfactory. Linnæus affirms, that the *distoma hepaticum* or *fluke* has been met with in fresh water; the *tænia vulgaris,*—of a smaller size, however,—in muddy springs; and the *ascarides vermiculares* in marshes, and in the putrescent roots of plants. Gadd affirms, that he met with the *tænia articulata plana osculis lateralibus geminis* in a chalybeate rivulet; Unzer, the *tænia* in a well; and Tissot says, that he found a *tænia,* exactly like the human, in a river; whilst Leeuenhoek, Schäffer and others affirm, that they have found the *distoma hepaticum* in water; but Müller,—who took extraordinary pains in the comparative examination of the entozoa, which infest the human body, with those that are met with in springs,—states, that he has frequently detected the *planariæ,* but never saw one like the *distoma hepaticum.*

On the other hand, the supporters of the equivocal theory have laboured, with a good deal of success, to show, that a difference is always discoverable between the worms found without and those within the body; but were it demonstrated to a mathematical certainty, that such difference exists, it would not be an invincible argument against the correctness of the univocal theory; as difference of locality, food, &c. might induce important changes in their corporeal developement, and give occasion to the diversity, which is occasionally perceptible amongst these parasites.

Yet, if we admit, that the germs of the *entozoa* are always received from without, their occurrence, in different stages of developement, in the fœtus in utero, is a circumstance difficult of explanation. Small, indeed, must be the germ, which, when received into the digestive organs of the mother, can pass into her circulation, be transmitted into the vessels of the fœtus, be deposited in some viscus and there undergo its full developement; yet such cases have occurred, if the theory be correct. Certain it is, however the fact may be accounted for, that worms have been found in the fœtus, by individuals whose testimony cannot be doubted. Eschholz saw them in the egg of the hen. Fromann found the *distoma*

hepaticum in the liver of the fœtal lamb; Kerckring, *ascarides lumbricoides* in the stomach of a fœtus six and a half months old; Brendel, *tæniæ* in the human fœtus in utero; Heim, *tæniæ* in the new-born infant; Blumenbach, *tæniæ*, in the intestine of the new-born puppy; and Göze, Bloch, and Rudolphi, the same parasite in sucking lambs.

Perhaps the conclusion of Cuvier is the soundest and most consistent with analogy, that these parasites "propagate by germs so minute as to be capable of transmission through the narrowest passages; so that the germs may exist in the infant at birth." We have seen, that not simply the germs, but the animals themselves have been found at this early period of existence.

The whole matter is involved in insuperable difficulties, but the univocal theory is, in all respects perhaps, most admissible as regards the whole of the living creation: still there are many distinguished naturalists, who conceive it probable, that spontaneous generation occurs in the lowest divisions of the living scale. Amongst these may be mentioned Lamarck, Raspail, Burdach, Treviranus, Wrisberg, Schweigger, Gruithuisen, Von Baer; and Adelon seems to accord with them.

The views of Lamarck, regarding the formation of living bodies, are strange in the extreme; and exhibit to us, what we so frequently witness, that, in order to get rid of a subject, which is difficult of comprehension, the philosopher will frequently explain facts, or adopt suppositions, that require a much greater stretch of the imagination to invent, and present stronger obstacles to belief than those for which they have been substituted. M. De Lamarck maintains, that the first organized beings were formed throughout, by a true spontaneous generation; their existence being owing to an excitative cause of life, probably furnished by the circumambient medium, and consisting of light and the electric fluid. When this cause meets with a substance of a gelatinous consistence, dense enough to retain fluids, it organizes the substance into a cellular tissue, and a living being results. This process, according to Lamarck, is occurring daily at the extremity of the vegetable and animal kingdoms.

The being, thus formed, manifested, originally, three faculties of life;—nutrition, growth, and reproduction,—but only in the most simple manner. The organization soon, however, became more complicated, for it is, he remarks, a property of the vital movement to tend always to a greater degree of developement of organization; to create particular organs, and to divide and multiply the different centres of activity; and, as reproduction constantly preserved all that had been acquired, numerous and diversified species were, in this manner, formed, possessing more and more extensive faculties. So that, according to this system, nature was directly concerned only in the first draughts of life; participating indirectly in the existence of living bodies of a more complex character; and these last proceeded from the former, after the lapse of an enormous

time, and an infinity of changes in the incessantly increasing complication of organization;—reproduction continuing to preserve all the acquired modifications, and improvements.

The simplest kind of generation does not require sexual organs. The animal, at a certain period of existence, separates into several fragments, which form so many new individuals. This is called *fissiparous generation*, or *generation by spontaneous division*. We have examples of it in the infusory animalcules—as the vinegar eel or *vibrio aceti*.

A somewhat more elevated kind of reproduction is the *gemmiparous*,—common in the vegetable kingdom,—and which consists in the formation of buds or *germs* on some part of the body. These, at a particular period, drop off, and form as many new individuals. According as the germs are developed at the surface of the body, or internally, the gemmiparous generation is said to be *external* or *internal*.

In these two varieties, the whole function is executed by a single individual.

Higher up in the scale, we find special organs for the accomplishment of generation—*male* and *female*. In those animals, however, that possess special reproductive organs, some have both sexes in the same individual, or are *hermaphrodite* or *androgynous*, as is the case with almost all plants, and with some of the lower tribes of animals.

In these, again, we notice a difference. Some are capable of reproduction without the concourse of a second individual; others, although possessing both attributes, require the concourse of another; the male parts of the one uniting with the female parts of the other. Both, in this way, become impregnated. The *helix hortensis* or *garden snail* affords us an instance of this kind of reproduction. They meet in pairs, according to Shaw, and stationing themselves an inch or two apart, launch several small darts, not quite half an inch long, at each other. These are of a horny substance, and sharply pointed at one end. The animals, during the breeding season, are provided with a little reservoir for them, situated within the neck, and opening on the right side. On the discharge of the first dart, the wounded snail immediately retaliates on its aggressor, by throwing a similar dart; the other renews the battle, and, in turn, is wounded. When the darts are expended, the war of love is completed, and its consummation succeeds.

In the superior animals, each sexual characteristic is possessed by a separate individual,—the species being composed of two individuals, male and female, and the concourse of these individuals, or of matters proceeding from them, being absolutely necessary for reproduction.

But here, again, two great differences are met with in the process. Sometimes the fecundating fluid of the male sex is not ap-

plied to the ovum of the female, until after its ejection by the latter, as in fishes. In other cases, the ovum cannot be fecundated after its ejection, and the fluid of the male sex is applied to it whilst still within the female, as in birds and the mammalia. In such case, the male individual is furnished with an organ for penetrating the parts of the female, and, in this kind of generation, there must be *copulation*.

Again, where there is copulation, the following varieties may exist. *First*. The ovum, when once fecundated, may be immediately laid by the female, and may be hatched out of the body, constituting *oviparous generation*. *Secondly*. Although the process of laying may commence immediately, the fecundated ovum may pass so slowly through the excretory passages, that it may be hatched there, and the new individual may issue from the womb of the parent possessing the proper formation. This constitutes *ovoviviparous generation*, of whch we have examples in the viper and salamander. *Thirdly*. The fecundated ovum may be detached from the ovary soon after copulation, but, in place of being ejected, it may be deposited in a reservoir, termed a *womb* or *uterus;* be fixed there; attract fluids from the organ adapted for its developement, and thus, increasing at the expense of the mother, be hatched, as it were, in this reservoir, so that the new individual may be born under its appropriate form. In such case, moreover, the new being, after birth, may be for a time supported on a secretion of the mother—the milk. These circumstances constitute *viviparous generation;* in which there are copulation, fecundation, gestation or pregnancy, and lactation or suckling. *Lastly*. There are animals, which, like the kangaroo, opossum and wombat, are provided with abdominal pouches, into which the young, born at a very early stage of developement, are received, and nourished with milk secreted from glands, contained within these pouches. Such animals are termed *marsupial*.

There is a considerable difference in animals as regards the nurturing care afforded by the parents to the young. Amongst the oviparous animals, many are satisfied with instinctively depositing their ova in situations, and under circumstances favourable to their hatching, and then abandoning them, so that they can never know their progeny. This is the case with insects. Others, again, as birds, subject their ova to incubation, and, after they have been hatched, administer nourishment to their young during the early period of existence. In the viviparous animal, these cares are still more extensive; the mother drawing from her own bosom the nutriment needed by the infant, or *suckling* it.

There are yet other varieties in the generation of animals. In some, it can be performed but once during the life of the individual; in others, we know it can be effected repeatedly. Sometimes one copulation fecundates but a single individual; at others, several generations are fecundated. A familiar example of this fecundity occurs in the common fowl, in which a single access will be suffi-

cient to fecundate the eggs for the season. In the insect tribe, this is still more strikingly exemplified. In the *aphis puceron* or *green-plant louse*, through all its divisions, and in the *monoculus pulex*, according to naturalists, a single impregnation suffices for at least six or seven generations. There is, in this case, another strange deviation from the ordinary laws of propagation, viz, that, in the warmer summer months, the young are produced viviparously, and, in the cooler autumnal months, oviparously.

A single impregnation of the queen bee will serve to fecundate all the eggs she may lay for two years at least. Hüber believes for the whole of her life, but he has had numerous proofs of the former. She begins to lay her eggs forty-six hours after impregnation, and will commonly lay about three thousand in two months, or at the rate of fifty eggs daily.

Lastly, the young are sometimes born with the shape which they have always to maintain; at others, under forms, which are, subsequently materially modified, as in the *papilio* or *butterfly* genus.

The reproduction of the human species requires the concourse of both sexes; these sexes being separate, and each possessed by a distinct individual—*male* and *female*. All the acts comprising it may be referred to five great heads, 1. *Copulation*, the object of which is to apply the fecundating principle, furnished by the male to the germ of the female. 2. *Conception* or *fecundation*, the prolific result of copulation. 3. *Gestation* or *pregnancy*, comprising the sojourn of the fecundated ovum in the uterus, and the developement it undergoes there. 4. *Delivery* or *accouchement*, which consists in the detachment of the ovum; its excretion and the birth of the new individual: and lastly, *lactation*, or the nourishing of the infant on the maternal milk.

Of the Generative Apparatus.

The part, taken by the two sexes in the process of generation, is not equally extensive. Man has merely to furnish the fluid, necessary for effecting fecundation, and to convey it within the female. He consequently participates only in copulation and fecundation; whilst, in addition, the acts of gestation and lactation are accomplished by the female. Her generative apparatus is therefore more complicated, and consists of a greater number of organs.

1. *Of the Genital Organs of the Male.*

The generative apparatus of the male comprises two orders of parts:—those which secrete and preserve the fecundating fluid, and those which accomplish copulation. The first consist of two similar glands—the *testes*—which secrete the *sperm* or fecundating fluid from the blood. 2. The excretory ducts of those glands—the *vasa deferentia*. 3. The *vesiculæ seminales*, which communicate with

the vasa deferentia and urethra; and 4. Two canals, called *ejaculatory*, which convey the sperm from the vesiculæ seminales into the canal of the urethra, whence it is afterwards projected externally. The second consists of the *penis*, an organ essentially composed of erectile tissues, and capable of acquiring considerable rigidity. These parts will require a more detailed notice.

Testes.—The testicles are two glands situated in a bag suspended beneath the pubes, called the *scrotum;* the right being a little higher than the left. They are of an ovoid shape, compressed laterally, their size being usually that of a pigeon's egg, and their weight about seven and a half, or eight drachms.

Like other glands, they receive arterial blood by an appropriate vessel, which communicates with the excretory duct. The *spermatic artery* conveys the blood, from which the secretion has to be operated, to the testicle. It arises from the abdominal aorta at a very acute angle, is small, extremely tortuous and passes down to the abdominal ring, through which it proceeds to the testicle. When it reaches this organ, it divides into two sets of branches, some of which are distributed to the epididymis, others enter the testicle at its upper margin, and assist in constituting its tissue.

The excretory ducts form, in the testicle, what are called the *seminiferous vessels* or *tubuli seminiferi.* These terminate in a white cord or nucleus, situated at the upper and inner part of the organ, where the excretory duct commences, and which is called the *corpus highmorianum* or *sinus of the seminiferous vessels.* Besides these anatomical elements of the testes, there are also—1. Veins, termed *spermatic*, which return the superfluous blood back to the heart. These arise in the very tissue of the organ, and form the *spermatic plexus*, the divisions of which collect in several branches, that pass through the abdominal ring, and unite into a single trunk, which subsequently divides again into another plexus, termed *corpus pampiniforme.* This has been described as peculiar to the human species, and as a diverticulum for the blood of the testicle, whose functions are intermittent. These veins ultimately terminate on the right side in the vena cava, and on the left in the renal vein. 2. Lymphatic vessels, in considerable number, the trunks of which, after having passed through the abdominal ring, open into the lumbar glands. 3. Nerves, partly furnished by the renal and mesenteric plexuses and by the great sympathetic, partly by the lumbar nerves, and which are so minute as not to be traceable as far as the tissue of the testicle. 4. An outer membrane or envelope to the whole organ, called *tunica albuginea* or *peritestis.* This is of an opaque white colour, of an evidently fibrous and close texture; it envelopes and gives shape to the organ; it also sends into the interior of the testicle numerous filiform, flattened prolongations, which constitute incomplete septa or partitions. These form triangular spaces, filled with seminiferous vessels, which pass, with considerable regularity, towards the superior margin and the corpus highmorianum.

These elements, united, constitute the testicle, the substance of which is soft, of a yellowish-gray colour, and divided by prolongations of the tunica albuginea, into a number of lobes and lobules. It seems to be formed of an immensity of very delicate, tortuous filaments, interlaced and convoluted in all directions, loosely united, and between which are ramifications of the spermatic arteries and veins.

According to Monro, Secundus, the seminiferous tubes of the testicle do not exceed the $\frac{1}{200}$th part of an inch in diameter, and, when filled with mercury, the $\frac{1}{120}$th part of an inch. He calculated, that the testis consists of 62.500 tubes, supposing each to be one inch long; and that, if the tubes were united, they would be 5208 feet and four inches long. The tubuli seminiferi finally terminate in straight tubes, called *vasa recta*, which unite near the centre of the testis, in a complicated arrangement, bearing the name *rete testis* or *rete vasculosum testis;* from this from 12 to 18 ducts proceed upwards and backwards to penetrate the corpus highmorianum and the tunica albuginea. These ducts are called *vasa efferentia.* Each of them is afterwards convoluted upon itself, so as to form a conical body, called *conus vasculosus*, having its base backwards; and, at its base, the tube of each cone enters the tube of which the epididymis is formed.

The epididymis is the prismatic arch, B, C. Fig. 143, which rests vertically on the back of the testicle and adheres to it by the reflection of the tunica vaginalis, so as to appear a distinct part from the body of the testis. It is enlarged at both ends; the upper enlargement being formed by the coni vasculosi, and called the *globus major;* the lower the *globus minor.* The epididymis is formed by a single convoluted tube, the fourth of a line in diameter. When the tube attains the lower end of the globus minor, it becomes less convoluted, enlarges, turns upwards, and obtains the name of *vas deferens.*

Fig. 143.

Male organs.

Left hand Fig. The testicle covered by its membranes, and seeming like one body.—*Right hand Fig.* The testicle freed from its outer coat.--A. Body of the testicle.--B. Commencement of the epididymis, or *globus major.*--C. The small head or *globus minor.*--D. The *vas deferens.*

The testes of most animals, that procreate but once a year, are comparatively small during the months when they are not excited. In man, the organ before birth, or rather during the greater part of gestation, is an abdominal viscus; but, about the seventh month of fœtal existence, it gradually descends through the abdominal ring into the scrotum, which it reaches in the eighth month, by a mechanism to be described hereafter. In some cases, it never descends, but remains in the cavity of the abdomen, giving rise to considerable mental distress in many instances, and exciting the idea, that there may be a total absence of the organs, or that, if they exist, they cannot effect the work of reproduction. The uneasiness is needless, the descent appearing to be by no means essential. It has been sufficiently demonstrated, that individuals, so circumstanced, are capable of procreation. In many animals, the testicles are always internal; whilst, in some, they appear only in the scrotum during the season of amorous excitement. Fodéré has indeed asserted, that the *crypsorchides*, or those whose testes have not descended, are occasionally remarked for the possession of unusual prolific powers and sexual vigour.*

It appears, that there is a set of barbarians at the back of the Cape of Good Hope, who are generally possessed of but one testicle, or are *monorchides;* and Linnæus, under the belief that this is a natural defect, has made them a distinct variety of the human species. Mr. Barrow has noticed the same singularity; but Dr. Good thinks it doubtful, whether, like the want of beard amongst the American savages, the destitution may not be owing to a barbarous custom of extirpation in early life. The deviation is not, however, more singular than the unusual formation of the nates and of the genital organs of the female in certain people of these regions, to which we shall have to refer.

The testicle is connected with the abdominal ring by means of the *spermatic cord*, a fasciculus of about half an inch in diameter, which can be readily felt through the skin of the scrotum. It is formed, essentially, of the vessels and nerves that pass to or from the testicle;—the spermatic artery, spermatic veins, lymphatics and nerves of the organ, and the vas deferens, or excretory duct. These are bound together by means of cellular tissue; and, externally, a membranous sheath of a fibrous character envelopes the cord, and keeps it distinct from the surrounding parts, and especially from the scrotum. When the cord has passed through the abdominal ring, its various elements are no longer held together, but each passes to its particular destination.

The *scrotum* or *purse* is a continuation of the skin of the inner side of the thighs, the perineum, and the penis. It is symmetrical,

* "Ces organes paraissant tirer du bain chaud où ils se trouvent plongés plus d'aptitude à la sécrétion que lorsqu'ils sont descendus au dehors dans leurs enveloppes ordinaires!"—*Traité de Médecine légale*, t. 1, p. 370.

the two halves being separated by a median line or *raphe.* The skin is of a darker colour here than elsewhere; is rugous, studded with follicles, and sparingly furnished with hair. This may be considered its outermost coat. Beneath this is the *dartos,*—a reddish, cellular membrane, which forms a distinct sac for each testicle; and a septum—the *septum scroti*—between them.

Much discussion has taken place regarding the nature of this envelope; some supposing it to be muscular, others cellular. Breschet and Lobstein affirm, that it does not exist in the scrotum before the descent of the testes, and they consider it to be formed by the expansion of the gubernaculum testis. Meckel, however, suggests, that it constitutes the transition between the cellular and muscular tissues, and that there exists between it and other muscles the same relation that there is between the muscles of the superior and inferior animals. It consists of long fibres considerably matted together, and passing in every direction, but which are easily separable by distention with air or water, and by slight maceration.

The generality of anatomists conceive it to be of a cellular character, yet it is manifestly contractile, corrugates the scrotum, and probably consists of muscular tissue also. Dr. Horner, indeed, affirms that he dissected a subject in January, 1830, in which the fibres were evidently muscular, although interwoven.

Beneath the dartos a third coat exists, which is muscular:—it is called the *cremaster* or *tunica erythroïdes.* It arises from the lesser oblique muscle of the abdomen, passes through the abdominal ring, aids in the formation of the spermatic cord, and terminates insensibly on the inner surface of the scrotum. It draws the testicle upwards.

The cellular substance, that connects the dartos and cremaster with the tunica vaginalis, has been considered by some as an additional coat, and termed *tunica vaginalis communis.*

The *tunica vaginalis* or *tunica elytroïdes* is a true serous membrane, enveloping the testicle and lining the scrotum; having, consequently, a scrotal and a testicular portion. We shall see, hereafter, that it is a dependence of the peritoneum, passing before the testicle in its descent, and afterwards becoming separated from any direct communication with the abdomen.

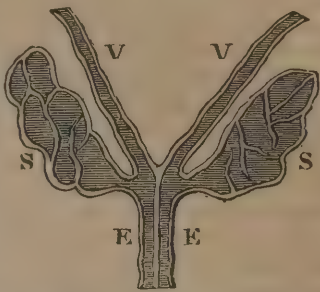
The *vas deferens* or excretory duct of the testicle commences at the globus minor of the epididymis, (C. Fig. 143,) which is itself, we have seen, formed of a convoluted tube. This, when unfolded, according to Monro, measures as much as thirty-two feet. As soon as the vas deferens quits the testicle, it joins the spermatic cord, passes upwards to the abdominal ring, separates from the blood-vessels on entering the abdomen, and descends downwards and inwards to the posterior and inferior part of the bladder, passing between the *bas-fond* of the latter and the ureter. It then converges towards its fellow along the under extremity of the bladder, at the inner margin of the vesicula seminalis of the same side, and ultimately opens into the urethra near the neck of the bladder. (Fig. 140.) At the base of

the prostate, it receives a canal from the vesicula, and continues its course to the urethra under the name of *ejaculatory duct.*

The vas deferens has two coats, the outermost of which is very firm and almost cartilaginous; but its structure is not manifest. The inner coat is thin, and belongs to the class of mucous membranes.

The *vesiculæ seminales*, E, Fig. 140, are considered to be two convoluted tubes,—one on each side,—which are two inches or two inches and a half long, and six or seven lines broad at the fundus, are situated at the lower fundus of the bladder, between it and the rectum and behind the prostate gland. At their anterior extremities they approach each other very closely, being separated only by the vasa deferentia. When inflated and dried, they present the appearance of cells; but are generally conceived to be tubes, which, being convoluted, are brought within the compass of the vesiculæ. When dissected and stretched out, they are four or five inches long by about one-fourth of an inch in diameter.—Amussat, however, denies this arrangement of the vesiculæ: he affirms, that he has discovered them to be formed of a minute canal of considerable length, variously convoluted, the folds of which are united to each other by cellular filaments, like those of the spermatic vessels.

Fig. 142.



Section of the vesiculæ seminales, &c.
V. Section of vas deferens.—S. Section of vesicula seminalis.—E. Section of ejaculatory duct.

At the anterior part, termed the *neck*, a short canal passes off, which unites at an acute angle with the vas deferens, to form the *ductus ejaculatorius.*

The vesiculæ are formed of two membranes; the more external like that of the vas deferens, and capable of contracting in the act of ejaculation; and an internal lining, of a white, delicate character, a little like that which lines the interior of the gall-bladder, and supposed to be mucous. Although the vesiculæ are manifestly contractile, no muscular fibres have been detected in them. They are found filled, in the dead body, with an opaque, thick, yellowish fluid, very different, in appearance, from the sperm ejaculated during life.

The *prostate gland*, Fig. 140, D, is an organ of a very dense tissue, embracing the neck of the bladder, and penetrated by the urethra, which traverses it much nearer its upper than its lower surface. The base is directed backwards, the point forwards, and its inferior surface rests upon the rectum, so that, by passing the finger into the rectum, enlargements of the organ may be detected.

The prostate was once universally esteemed glandular, and it is still so termed. It is, now, generally and correctly regarded as an

agglomeration of several small follicles, filled by a viscid whitish fluid. These follicles have numerous minute excretory ducts, which open on each side of the caput gallinaginis.

The *glands of Cowper* are two small, oblong bodies; of the size of a pea; of a reddish colour, and of a somewhat firm tissue. They are situated anterior to the prostate, parallel to each other, and at the sides of the urethra. Each has an excretory duct, which creeps obliquely in the spongy tissue of the bulb, and opens before the verumontanum.

The *male organ* or *penis* consists of the *corpus cavernosum* and *corpus spongiosum;* parts essentially formed of an erectile tissue, and surrounded by a very firm elastic covering, which prevents over-distention, and gives form to the organ.

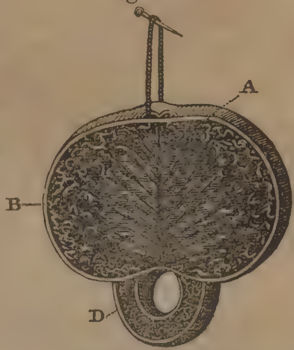
The *corpora cavernosa* constitute the great body of the penis. They are two tubes which are united and separated by an imperfect partition. Within them a kind of cellular tissue exists, into which blood is poured, so as to cause erection. The posterior extremities of these cavernous tubes are called *crura penis.* These separate in the perineum, each taking hold of a ramus of the pubis; and, at the other extremity, the cavernous bodies terminate in rounded points under the glans penis. The anatomical elements of the internal tissue of the corpora cavernosa, are,—the ramifications of the *cavernous artery*, which proceeds from the internal pudic; those of a vein bearing the same name; and, probably, nerves, although they have not been traced so far. All these elements are supported by filamentous prolongations from the outer dense envelope. A difference of opinion prevails amongst anatomists with regard to the precise arrangement of these prolongations. Some consider them to form cells, or a kind of spongy structure, on the plates of which the ramifications of the cavernous artery and vein and of the nerves terminate, and into which the blood is extravasated.

Others conceive, that the internal arrangement consists of a plexus of minute arteries and veins, supported by the plates of the outer membrane, interlacing like the capillary vessels, but with this addition, that, in place of the minute veins becoming capillary in the plexus, they are of greater size, forming very extensible dilatations and net-works, and anastomosing freely with each other. If the cavernous artery be injected, the matter first fills the ramifications of the artery, then the venous plexus of the cavernous bodies, and it ultimately returns by the cavernous vein, having produced erection. The same effect is caused still more readily by injecting the cavernous vein.

Attached to the corpora cavernosa of the penis, and running in the groove beneath them, is a spongy body, of a similar structure,—the *corpus spongiosum urethræ*,—through which the urethra passes. It commences, posteriorly, at the bulb of the urethra,—already described under the *Secretion of Urine*,—and terminates, anteriorly,

in the *glans*, which is, in no wise, a dependency of the corpora cavernosa, but is separated from them by a portion of their outer membranes; so that erection may take place in the one, and not simultaneously in the other; and injections into the corpora cavernosa of the one do not pass into those of the other. The glans appears to be the final expansion of the erectile tissue which surrounds the urethra. The posterior circular margin of the glans is called the *corona glandis*, and behind this is a depression termed the *cervix*, *collum* or *neck*. Several follicles exist here, called the *glandulæ odoriferæ Tysoni*, which secrete an unctuous humour, called the *smegma præputii*, which often accumulates largely, where cleanliness is not attended to.

Fig. 129.



Section of the Penis.

A. External membrane or sheath of the penis.—B. Corpus cavernosum.—D. Corpus spongiosum urethræ.

The penis is covered by the skin, which forms, towards the glans, the *prepuce* or *foreskin*. The cellular tissue, which unites it to the organ is lax, and never contains fat. The inner lamina of the prepuce being inserted circularly into the penis, some distance back from the point, the glans can generally be denuded, when the prepuce is drawn back. The under and middle part of the prepuce is attached to the extremity of the glans by a duplicature, called the *frænum præputii*, which extends to the orifice of the urethra.

The skin is continued over the glans, but it is greatly modified in its structure, being smooth and velvety, highly delicate, sensible, and vascular.

Lastly.—In addition to the *acceleratores urinæ*, the *transversus perinei*, the *sphincter ani*, and the *levator ani* muscles, which we have described as equally concerned in the excretion of urine and semen, the *erector penis* or *ischio-cavernosus* muscle is largely connected with the function of generation.

The genital organs of man are, in reality, merely an apparatus for a glandular secretion, of which the testicle is the gland; the vesiculæ seminales are supposed to be the reservoirs; and the vas deferens and urethra the excretory ducts;—the arrangement which we observe in the penis being for the purpose of conveying the secreted fluid into the parts of the female.

The *sperm* or *semen* is secreted by the testicles from the blood of the spermatic artery, by a mechanism, which is no more understood than that of secretion in general. When formed, it is received into the tubuli seminiferi, and passes along them to the epididymis, the vas deferens, and the vesiculæ seminales, where it is generally conceived to be deposited, until it is projected into the urethra, under the venereal excitement. That this is its course is sufficiently evi-

denced by the arrangement of the excretory ducts, and by the function which the sperm has to fulfil. De Graaf, however, adduces an additional proof. On tying the vas deferens of a dog, the testicle became swollen under excitement, and ultimately the vas deferens gave way between the testicle and the ligature.

The causes of the progression of the sperm through the ducts are,—the continuity of the secretion by the testicle, and a contraction of the excretory ducts themselves. These are the efficient agents.

It has been a question with physiologists, whether the secretion of the sperm is constantly taking place, or whether, as the function of generation is accomplished at uncertain intervals, the secretion may not likewise be intermittent. It is impossible to arrive at any positive conclusion on this point. It would seem, however, unnecessary for the secretion to be effected at all times; and it is more probable, that when the vesiculæ seminales are emptied of their contents, during coition, a stimulus is given to the testes by the excitement, and they are soon replenished. This, however, is more and more difficult in proportion to the number of repetitions of the venereal act, as the secretion takes place at best but slowly.

By some, the spermatic and pampiniform plexuses have been regarded as diverticula to the testes during this intermission of action.

The sperm passes slowly along the excretory ducts of the testicle, owing partly to the slowness of the secretion, and partly to the arrangement of the ducts, which, as we have seen, are remarkably convoluted, long, and minute.

The use of the vesiculæ seminales has been disputed. The majority of physiologists regard them to be reservoirs for the sperm, and to serve the same purpose as the gall-bladder in the case of the bile. Others, however, have supposed, that they secrete a fluid of a peculiar nature, the use of which may probably be to dilute the sperm. They are manifestly not essential to the function, as they do not exist in all animals. The dog and cat kind, the bear, opossum, sea-otter, seal, &c., possess them not; and there are several in which there is no direct communication between the duct and the vas deferens, which open separately into the urethra. This circumstance, however, with the fact, that they generally contain, after death, a fluid of different appearance and properties from those of the sperm, with the glandular structure, which their coats seem to possess in many instances, is opposed to the view, that they are simple reservoirs for the semen, and favours that which ascribes to them a peculiar secretion. Where this communication between the duct of the vesicles and the vas deferens exists, a reflux of the semen may take place, and an admixture between the sperm and the fluid secreted by them. It is not improbable, however, as Adelon suggests, that all the excretory ducts of the testicle may act as a reservoir; and, in the case of animals, in which the vesiculæ are wanting, they must possess this office exclusively. If we are to adopt the descrip-

tion of Amussat as an anatomical fact, the vesiculæ themselves are constituted of a convoluted tube, having an arrangement somewhat resembling that which prevails in the excretory ducts of the testis.

But how, it has been asked, does it happen, that the sperm, in its progress along the vas deferens, does not pass directly on into the urethra by the ejaculatory duct, instead of reflowing into the spermatic vesicles? This, it has been imagined, is owing to the existence of an arrangement at the opening of the ejaculatory duct into the urethra, similar to that which prevails at the termination of the choledoch duct in the duodenum. It is affirmed, by some, that the prostate exerts a pressure on the ductus ejaculatorius, and that the opening of the duct into the urethra is smaller than any other part of it; by others, that the ejaculatory ducts are embraced, along with the neck of the bladder, by the levator ani, and consequently, that the sperm finds a readier access into the ducts of the vesiculæ seminales.

The sperm is of a white colour, and of a faint smell, which, owing to its peculiar character, has been termed *spermatic*. It is of a viscid consistence, of a saline, irritating taste, and appears composed of two parts, the one more liquid and transparent, and the other more grumous. In a short time after emission, these two parts unite and the whole becomes more fluid. When examined chymically, the sperm appears to be of an alkaline, and albuminous character. Vauquelin analyzed it and found it to be composed,—in 1000 parts,—of water, 900; animal mucilage, 60; soda, 10; calcareous phosphate, 30. Berzelius affirms, that it contains the same salts as the blood along with a peculiar animal matter. After citing these analyses, Raspail observes, that if anything be capable of humiliating the pride of the chymist, it is assuredly the identity he is condemned to discover amongst substances, which, notwithstanding, fulfil such different functions.

No analysis has been made of the sperm as secreted by the testicle. The fluid examined has been the compound of the pure sperm and the secretions of the prostate gland and of those of Cowper. The thicker, whitish portion, is considered to be the secretion of the testicles;—the more liquid and transparent, the fluids of the accessory glands or follicles.

Some authors have imagined, that a sort of halitus or aura is given off from the sperm, which they have called the *aura seminis*, and have considered to be sufficient for fecundation. The fallacy of this view will be exhibited hereafter. Others have discovered, by the microscope, numerous minute bodies in the sperm, which they have conceived to be important agents in generation. These animalcules, however, have been denied to be peculiar to this fluid, and have been regarded as infusory animalcules, similar to those met with in all animal infusions; by others, they have been esteemed organic molecules of the sperm. Virey,—a physiologist, strangely fantastic in his speculations,—conceives, that as the pollen of vege-

tables is a collection of small capsules, containing within them the true fecundating principle, which is of extreme subtilty, the pretended spermatic animalcules are tubes containing the true sperm, and the motion we observe in them is owing to the rupture of the tubes; whilst Raspail is led to think, that they are mere shreds (*lambeaux*) of the tissues of the generative organs, ejaculated with the sperm, and which describe involuntary movements by virtue of the property they possess of *aspiring* and *expiring*. In confirmation of this, he states, that if we open an ovary of the mussel, we may observe alongside the large ovules, myriads of moving shreds, whose form and size are infinitely varied, and which possess nothing resembling regular organization. They bear evident marks of laceration. Now, these shreds, he conceives, may affect greater regularity in certain classes of animals of a more elevated order; but, he concludes, that however this may be, the spermatic animalcules, which have hitherto been classed amongst those *incertæ sedis*, may be provisionally placed in the genus *cercaria* —that is, amongst infusory, agastric animals having a kind of tail—which Raspail considers the simplest of animated beings, and to live only by "aspiration and expiration."

The Author has frequently examined the sperm with the microscope, but without being able to satisfy himself, that the minute bodies, contained in it, are animalcular. In the hydroxygen microscope of Dr. Weldon, not the slightest appearance of animalcules presented itself, on two different occasions, when the sperm was examined: on one of these occasions, the Author was present.

The agency of the sperm in fecundation will be considered hereafter. It may be observed, however, that in all examinations of it, whether by the microscope or otherwise, we must bear in mind, the caution to which we have adverted more than once as applicable to the examination of animal fluids in general,—that we ought not to conclude, positively, from the results of our observations of the fluids when out of the body, that they possess precisely the same characteristics when in it; and this remark is especially applicable to the sperm, which varies manifestly in its sensible properties a short time after it has been excreted.

The sperm being the great vivifying agent,—the medium by which life is communicated from generation to generation,—it has been looked upon as one of the most important if not the most important of animal fluids; and hence it is regarded, by some physiologists, as formed of the most animalized materials, or of those that constitute the most elevated part of the new being—the nervous system.

The quantity of sperm secreted cannot be estimated. It varies according to the individual, and to his extent of voluptuous excitement, as well as to the degree of previous indulgence in venereal pleasures. Where the demand is frequent, the supply is larger;

although, when the act is repeatedly performed, the absolute quantity at each copulation may be less.

2. *Genital Organs of the Female.*

The genital organs of the male effect fewer functions than those of the female. They are inservient to copulation and fecundation only. Those of the female,—in addition to parts, which fulfil these offices,—comprise others for gestation, and lactation.

The soft and prominent covering to the symphysis pubis—which is formed by the common integuments, elevated by fat, and, at the age of puberty, covered by hair, formerly termed *tressoria*, is called the *mons veneris.* The absence of this hair has, by the vulgar, been esteemed a matter of reproach; and it was formerly the custom, when a female had been detected a third time in incontinent practices, in the vicinity of the Superior Courts of Westminster, to punish the offence by cutting off the *tressoria* in open court. Below this, are the *labia pudendi* or *labia majora,* which are two large soft lips, formed by a duplicature of the common integuments, with adipous matter interposed. The inner surface is smooth, and studded with sebaceous follicles. The labia commence at the symphysis pubis, and descend to the *perineum,* which is the portion of integument, about an inch and a half in length, between the posterior commissure of the labia and the anus. This commissure is called the *frænum labiorum* or *fourchette.* The opening between the labia is the *vulva* or *fossa magna.*

At the upper junction of the labia, and within them, a small organ exists, called the *clitoris* or *superlabia*, which greatly resembles the penis. It is formed of corpora cavernosa, and is terminated, anteriorly, by the *glans,* which is covered by a prepuce, consisting of a prolongation of the mucous membrane of the vagina. Unlike the penis, however, it has no corpus spongiosum, or urethra attached to it; but it is capable of being made erect by a mechanism similar to that which applies to the penis, and has two erector muscles—the *erectores clitoridis,*—similar to the erectores penis. Anciently, if a female was detected a fourth time in incontinence in the vicinity of the Superior Courts of Westminster, the clitoris was amputated in open court.

From the prepuce of the clitoris, and within the labia majora, are the *labia minora* or *nymphæ,* the organization of which is similar to that of the labia majora. They gradually enlarge as they pass downwards, and disappear when they reach the orifice of the vagina.

A singular variety is observed in the organization of those parts amongst the Bosjesmen or Bushmen, the tribe to whose peculiarities of organization we have already had occasion to refer. Discordance has, however, prevailed regarding the precise nature of this peculiarity, some describing it as existing in the labia, others

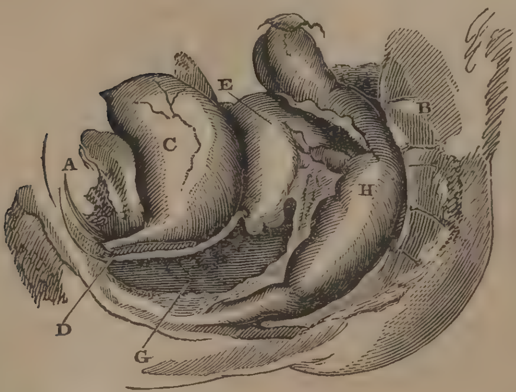
in the nymphæ, and others, again, in a peculiar organization; some deeming it natural, others artificial. Dr. Somerville, who had numerous opportunities for observation and dissection, asserts, that the mons veneris is less prominent than in the European, and is either destitute of hair, or thinly covered by a small quantity of a soft, woolly nature; that the labia are very small, so that they seem at times to be almost wanting; that the loose, pendulous, and rugous growth, which hangs from the pudendum, is a double fold; and that it is proved to be the nymphæ, by the situation of the clitoris at the commissure of the folds, as well as by all other circumstances; and that they sometimes reach five inches below the margin of the labia; Le Vaillant says nine inches.

Cuvier examined the Hottentot Venus, and found her to agree well with the account of Dr. Somerville. The labia were very small; and a single prominence descended between them from the upper part. It divided into two lateral portions, which passed along the sides of the vagina to the inferior angle of the labia. The whole length was about four inches. When she was examined, naked, by the French *Savans*, this formation was not observed. She kept the *tablier*, *ventrale cutaneum*, or, as it is termed by the Germans, schürze ('apron'), carefully concealed, either between her thighs, or yet more deeply; and it was not known, until after her death, that she possessed it.

Both Mr. Barrow and Dr. Somerville deny, that the peculiarity is artificially excited.

In warm climates, the nymphæ are often greatly and inconveniently elongated, and, amongst the Egyptians and other African tribes, it has been the custom to extirpate them, or to diminish their size. This is what is meant by *circumcision* in the female.

Fig. 146.



Lateral view of the Female organs.

A. Section of os pubis.—B. Section of spine and sacrum.—C. Urinary bladder, moderately distended, and rising behind the pubis.—D. The urethra.—E. The uterus.—G. The vagina, embracing the neck of the womb, with the os uteri projecting into it.

The *vagina* is a canal, which extends between the vulva and the uterus, the neck of which it embraces.

It is sometimes called the *vulvo-uterine canal*, and is from four to six inches long, and an inch and a half, or two inches in diameter.

It is situated in the pelvis, between the bladder before, and the rectum behind; is slightly curved, with the concavity forwards, and is narrower at the middle than at the extremities. Its inner surface has numerous—chiefly transverse—rugæ, which become less in the progress of age, after repeated acts of copulation, and espepecially after accouchement.

The vagina is composed of an internal mucous membrane, supplied with numerous mucous follicles, of a dense cellular membrane, and, between these, a layer of erectile tissue, which is thicker near the vulva; but is, by some, said to extend even as far as the uterus. It is termed the *corpus spongiosum vaginæ.* It is chiefly situated around the anterior extremity of the vagina, below the clitoris, and at the base of the nymphæ: the veins of which it is constituted are called *plexus retiformis.* The upper portion of the vagina, to a small extent, is covered by the peritoneum.

The *sphincter* or *constrictor vaginæ muscle* surrounds the orifice of the vagina, and covers the plexus retiformis. It is about an inch and a quarter wide; arises from the body of the clitoris, and passes backwards and downwards, to be inserted into the dense, white substance, in the centre of the perineum, which is common to the transversi perinei muscles, and the anterior point of the sphincter ani.

Near the external aperture of the vagina, is the *hymen*, or *virginal*, or *vaginal valve*, which is a more or less extensive, membranous duplicature, of variable shape, and formed by the mucous membrane of the vulva where it enters the vagina, so that it closes the canal, more or less completely. It is generally very thin, and easily lacerable; but is sometimes extremely firm, so as to prevent penetration. It is usually of a semilunar shape; sometimes oval, from right to left, or almost circular, with an aperture in the middle, whilst, occasionally, it is entirely imperforate, and of course prevents the issue of the menstrual flux. It is easily destroyed by mechanical violence of any kind, as by strongly rubbing the sexual organs of infants by coarse cloths, and by ulcerations of the part; hence its absence is not an absolute proof of the loss of virginity, as it was of old regarded by the Hebrews. Nor is its presence a positive evidence of continence. Individuals have conceived, in whom the aperture of the hymen has been so small as to prevent penetration. Its semilunar or crescentic shape has been considered to explain the origin of the symbol of the *crescent* assigned to Diana—the goddess of chastity.

Around the part of the vagina, where the hymen was situated, small, reddish, flattened, or rounded tubercles afterwards exist, which are of various sizes, and are formed, according to the general opinion, by the remains of the hymen; but Béclard considers them to be folds of the mucous membrane. Their number varies from two to five, or six.

Fig. 147.

Anterior view of the female organs.

The *uterus* is a hollow organ, for the reception of the fœtus, and its retention during gestation. It is situated in the pelvis, between the bladder, which is before, and the rectum behind, and below the convolutions of the small intestines. Fig. 146 gives a lateral view of their relative situation, and Fig. 147, of their position, when regarded from before. It is of a conoidal shape, flattened on the anterior and posterior surfaces; rounded at the base, which is above, and truncated at its apex, which is beneath. It is of small size; its length being only about two and a half inches; its breadth one and

Fig. 148.

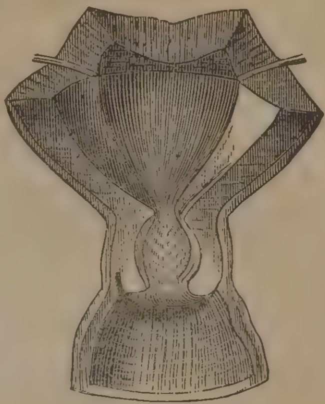
Female organs.

a. Fundus uteri.—*b.* Body of the uterus.—*c.* Neck of the uterus.—*d.* Os uteri.—*e.* Vagina.—*f, f.* Fallopian tubes.—*g, g.* Broad ligaments of the uterus.—*h, h.* Round ligaments.—*p, p.* Fimbriated extremities of the Fallopian tube.—*o, o.* Ovaries.—*l, l.* Ligaments of the ovary.

a half inch at the base, and ten lines at the neck; its thickness about an inch.

It is divided into the *fundus*, *body*, and *cervix* or *neck*. The fundus is the upper part of the organ, which is above the insertion of the Fallopian tubes. The body is the part between the insertion of the tubes and the neck; and the neck is the lowest and narrowest portion, which projects and opens into the vagina.

Fig. 149.



Interior of the uterus.

At each of the two superior angles are—the opening of the Fallopian tube, the attachment of the ligament of the ovary, and that of the round ligament. The inferior angle is formed by the neck, which projects into the vagina to the distance of four or five lines, and terminates by a cleft, situated crosswise, called *os tincæ*, *os uteri*, or *vaginal orifice of the uterus*. The aperture is bounded by two lips, which are smooth and rounded in those that have not had children; jagged and rugous in those who are mothers,—the anterior lip being somewhat thicker than the posterior. It is from three to five lines long, and is generally more or less open, especially in those who have had children.

The internal cavity of the uterus is very small in proportion to the bulk of the organ, owing to the thickness of the parietes, which almost touch internally. It is divided into the cavity of the body, and that of the neck, (Fig. 149.) The former is triangular. The tubes open into its upper angles. The second cavity is more long than broad; is broader at the middle than at either end, and at the upper part, where it communicates with the cavity of the body of the uterus, an opening exists, called the *internal orifice* of the uterus: the external orifice being the os uteri. The inner surface has several transverse rugæ, which are not very prominent. It is covered by very fine villi, and the orifices of several mucous follicles are visible.

Fig. 150.

Section of the uterus

The marginal figure exhibits the cavity of the uterus, as seen by a vertical lateral section.

The precise organization of the uterus has been a topic of interesting inquiry amongst anatomists. It is usually considered to be formed of two parts, a mucous membrane internally, and the proper tissue of the uterus, which constitutes the principal part of the substance.

The mucous membrane has been esteemed a

prolongation of that which lines the vagina. It is very thin; of a red hue in the cavity of the body of the organ; white in that of the neck. Chaussier, Ribes and Madame Boivin, however, deny its existence. Chaussier asserts, that having macerated the uterus and a part of the vagina in water, in vinegar, and in alkaline solutions; and having subjected them to continued ebullition, he always observed the mucous membrane of the vagina stop at the edge of the os uteri; and Madame Boivin,—a well-known French authoress on obstetrics, who has attended carefully to the anatomy of those organs during pregnancy,—says, that the mucous membrane of the vagina terminates by small expansible folds, and by a kind of prepuce, under the anterior lip of the os uteri. In their view, the inner surface of the uterus is formed of the same tissue as the rest of it. The proper tissue of the organ is dense, compact, not easily cut, and somewhat resembles cartilage in colour, resistance, and elasticity. It is a whitish, homogeneous substance, penetrated by numerous minute vessels. In the unimpregnated state, the fibres, which seem to enter into the composition of the tissue, appear ligamentous and pass in every direction, but so as to permit the uterus to be more readily lacerated from the circumference to the centre than in any other direction. The precise character of the tissue is a matter of contention amongst anatomists. To judge from the changes it experiences during gestation, and by its energetic contraction in delivery, it would seem to be decidedly muscular, or at least capable of assuming that character; but, on this point, we shall have occasion to dwell hereafter.

The uterus has,—besides the usual organic constituents,—arteries, veins, lymphatics, and nerves. The arteries proceed from two sources;—from the spermatic, which are chiefly distributed to the fundus of the organ, and towards the part where the Fallopian tubes terminate; and from the hypogastric, which are sent especially to the body and neck. Their principal branches are readily seen under the peritoneum, which covers the organ: they are very tortuous; frequently anastomose, and their ramifications are lost in the tissue of the viscus, and on its inner surface. The veins empty themselves partly in the spermatic, and partly in the hypogastric. They are even more tortuous than the arteries; and, during pregnancy, they dilate and form what have been termed the *uterine sinuses*. The nerves are derived partly from the great sympathetic, and partly from the sacral pairs.

The appendages of the uterus are:—1. The *ligamenta lata* or *broad ligaments*, which are formed by the peritoneum. This membrane is reflected over the anterior and posterior surfaces and over the fundus of the uterus, and the lateral duplicatures of it form a broad expansion, and envelope the Fallopian tubes and ovaria. These expansions are the broad ligaments. (See Fig. 148, *g*, *g*, and Fig. 147.) 2. The *anterior* and *posterior ligaments*, which are four in number and are formed by the peritoneum. Two of these pass from the

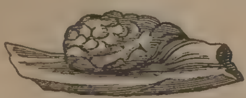
uterus to the bladder,—the *anterior;* and two between the rectum and uterus,—the *posterior.* 3. The *ligamenta rotunda* or *round ligaments,* which are about the size of a goose-quill, arise from the superior angles of the fundus uteri, and, proceeding obliquely downwards and outwards, pass out through the abdominal rings to be lost in the cellular tissue of the groins. They are whitish, somewhat dense, cords, formed by a collection of tortuous veins and lymphatics, of nerves, and of longitudinal fibres, which were, at one time, believed to be muscular, but are now generally considered to consist of condensed cellular tissue. Meckel thinks, that these different ligaments contain, between the layers composing them, muscular fibres, which are more or less marked, and which proceed from the lateral margin of the uterus. 4. The *Fallopian* or *uterine tubes;* two conical, tortuous canals, four or five inches in length; situated in the same broad ligaments that contain the ovaries, and extending from the superior angles of the uterus as far as the lateral parts of the brim of the pelvis. (Figs. 147, 148, and 151.) The uterine extremity of the tube (Figs. 149 and 151,) is extremely small, and opens into the uterus by an aperture so minute, as to scarcely admit a hog's bristle. The other extremity is called the *pavilion.* It is trumpet-shaped, fringed, and commonly inclined towards the ovary, to which it is attached by one of its longest fimbriæ. This fringed portion is called *corpus fimbriatum* or *morsus diaboli.* The Fallopian tubes, consequently, open at one end into the cavity of the uterus, and at the other through the peritoneum into the cavity of the abdomen. They are covered externally by the broad ligament, or peritoneum; are lined internally by a mucous membrane, which is soft, villous, and has many longitudinal folds; and between these coats is a thick, dense, whitish membrane, which is possessed of contractility; although muscular fibres cannot be detected in it. Santorini asserts, that in robust females the middle membrane of the tubes has two muscular layers; an external, the fibres of which are longitudinal, and an internal, whose fibres are circular.

Fig. 151.

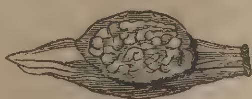
Fallopian tube.

The *ovaries,* (Figs. 148 and 152,) are two ovoid bodies, of a pale red colour, rugous, and nearly of the size of the testes of

Fig. 152.

a. 

Ovary.

b. 

Section of ovary.

the male. They are situated in the cavity of the pelvis, and are contained in the posterior fold of the broad ligaments of the uterus. At one time they were conceived to be glandular, and were called the female testes; but as soon as the notion prevailed, that they contained ova, the term *ovary* or *egg-vessel* was given to them. The external extremity of the ovary has attached to it one of the principal fimbriæ of the Fallopian tube. The inner extremity has a small fibro-vascular cord inserted into it: this passes to the uterus to which it is attached behind the insertion of the Fallopian tube, and a little lower. It is called the *ligament of the ovary*, and is in the posterior ala of the broad ligament. It is solid, and has no canal.

The surface of the ovary has many round prominences, and the peritoneum envelopes the whole of it, except at the part where the ovary adheres to the broad ligament. The precise nature of its parenchyma is not determined. When torn or divided longitudinally, as in Fig. 152, *b*, it appears to be constituted of a cellulo-vascular tissue. In this, there are from fifteen to twenty spherical vesicles—*ovula Graafiana*—varying in size from half a line to three lines in diameter. These are filled with an albuminous fluid, which is colourless or yellowish, and may be readily seen by dividing the vesicles carefully with the point of a pair of fine scissors.

The arteries and veins of the ovaries belong to the spermatics. Their nerves, which are extremely delicate, are from the renal plexuses; and their lymphatics communicate with those of the kidneys.

Such is the anatomy of the chief organs, concerned in the function of generation. Those of lactation we shall describe hereafter.

The sexual characteristics, in the human species, are widely separate; and the two sexes are never, perhaps, united in the same individual. Yet such an unnatural union has been supposed to exist; from the fabulous son of Ἑρμης and Αφροδιτη,—Mercury and Venus,—to his less dignified representatives of modern times:—

> "Nec fœmina dici,
> Nec puer ut possent, neutrumque et utrumque videntur."—OVID.*

We have already remarked, that in the lower animals and in plants, such hermaphrodism is common; but, in the upper classes, and especially in man, a formation, which gives to an individual the attributes of both sexes, has never been witnessed. Monstrous formations are occasionally met with; but, if careful examination be made, it can usually be determined to what sex they rather belong. Cases, however, occur in which it is extremely difficult to decide, although we may readily pronounce that the being is totally incapable of the function of reproduction. The generality of cases are produced by unusual developements of the clitoris in the female, or

* "Both bodies in a single body mix,
A single body with a double sex."—ADDISON.

by a cleft scrotum in the male. Only two instances of the kind have fallen under the observation of the author, both of which were females, as they usually are. One of these has been described by the late Professor Béclard, of Paris, whose details we borrow.

Marie-Madeleine Lefort, aged sixteen years, seemed to belong to the male sex, if attention were paid merely to the proportions of the trunk, limbs, shoulders, and pelvis; to the conformation and dimensions of the pelvis; to the size of the larynx; the tone of the voice, the developement of the hair; and to the form of the urethra, which extended beyond the symphysis pubis. An attentive examination, however, of the genital organs showed, that she was of the female sex. The mons veneris was round and covered with hair. Below the symphysis pubis was a clitoris, resembling the penis in shape, twenty-seven millimètres, or about an inch long in the state of flaccidity; and susceptible of slight elongation during erection; having an imperforate glans, hollowed beneath by a duct or channel, at the inferior part of which were five small holes, situated regularly on the median line.

Beneath and behind the clitoris a vulva existed, with two narrow, short and thin labia, furnished with hair, devoid of anything like testicles, and extending to within ten lines of the anus. Between the labia was a very superficial cleft, pressure upon which communicated a vague sensation of a void space in front of the anus. At the root of the clitoris was a round aperture, through which a catheter could not be passed into the bladder. It could be readily directed, however, towards the anus, in a direction parallel to the perineum.

When the catheter was passed a little backwards and upwards to the depth of eight or ten centimètres it was arrested by a sensible obstacle, but no urine flowed through it. It seemed to be in the vagina. At the part where the vagina stopped, a substance could be distinguished through the parietes of the rectum, which appeared to be the body of the uterus. Nowhere could testicles be discovered. She had menstruated from the age of eight years; the blood issuing in a half coagulated state through the aperture at the root of the clitoris. She experienced, too, manifest inclination for commerce with the male, and a slight operation only would probably have been necessary to divide the apron closing the vulva from the clitoris to the posterior commissure of the labia. The urethra extended in this case for some distance beneath the clitoris, as in the penis. From all the circumstances, M. Béclard concluded, that the person, subjected to the examination of the *Société de Médecine* of Paris, was a female; and that she possessed several of the essential organs of the female;—the uterus, and vagina—whilst she had only the secondary characters of the male;—as the proportions of the trunk and limbs; that of the shoulders and pelvis; the conformation and dimensions of the pelvis; the size of the larynx; the tone of the

voice; the developement of the hair; the urethra extending beyond the symphysis pubis, &c.

In the year 1818, an individual was exhibited in London, who had a singular union of the apparent characteristics of the two sexes. The countenance resembled that of the male, and she had a beard, but it was scanty. The shape, however, of the body and limbs was that of the female. The students of the Anatomical Theatre of Great Blenheim street, London, of whom the author was one, offered her a certain sum, provided she would permit the sexual organs to be inspected by the veteran head of the school—Mr. Brookes: to this she consented. She was, accordingly, exposed before the class; and her most striking peculiarities exhibited. The clitoris was large, but not perforate. Mr. Brookes, desirous of trying the *experimentum crucis*, passed one catheter into the vagina, and attempted to introduce another into the urethra; but fearing discovery, and finding that the mystery of her condition was on the point of being unveiled, she started up and defeated the experiment. No doubt existed in the mind of Mr. Brookes, that there were two distinct canals,—one forming the vagina; the other the urethra,—and that she was consequently female.

One of the most complete cases of admixture of the sexes, was laid by Rudolphi before the *Academy of Sciences* of Berlin. It was met with in the body of a child, which died, it was said, seven days after birth, but the developement of parts led to the supposition, that it was three months old. The penis was divided inferiorly; the right side of the scrotum contained a testicle; the left side was small and empty. There was a uterus, which communicated at its superior and left portion with a Fallopian tube, behind which was an ovary destitute of its ligament. On the right side, there was neither Fallopian tube, nor ovary, nor ligament, but a true testicle, from the epididymis of which arose a vas deferens. Below the uterus was a hard, flattened ovoid body, which, when divided, exhibited a cavity with thick parietes. The uterus terminated above in the parietes of this body, but without penetrating its cavity. At its inferior part was a true vagina, which terminated in a cul-de-sac. The urethra opened into the bladder, which was perfect; and the anus, rectum and other organs were naturally formed. Rudolphi considered the ovoid body, situated beneath the uterus, to be the prostate, and vesiculæ seminales in a rudimental state.

Cases like these,—and we have such on the authority of Verdier, Pinel, Maret, Sue, Bouillaud, and others,—have led to the belief, that hermaphrodism is possible. This is the opinion of Tiedemann, Meckel, and many other physiologists, but it does not rest on any observed examples.

The varieties of these sexual vagaries are extremely numerous; and form occasionally the subject of medico-legal inquiry.

Instances of animals being brought forth, whose organs of generation are preternaturally formed, sometimes occur, and they also

have been commonly called *hermaphrodites;* but such examples have been rarely investigated.

Monstrous productions, having a mixture of the male and female organs, seem to arise most frequently in neat cattle, and have been called *free-martins.* When a cow brings forth twin calves, one a male and the other apparently a female, the former always grows up to be a perfect bull, but the latter appears destitute of all sexual functions and propensities, and never propagates. This is the *free-martin.*

From Mr. Hunter's observations it would seem, that in all the instances of free-martins, which he examined, no one had the complete organs of the male and female, but partly the one and partly the other; and, in all, the ovaria and testicles were too imperfect to perform their functions.

In noticing this phenomenon, Sir Everard Home remarks, that it may account for twins being most commonly of the same sex; "and when they are of different sexes," he adds, "it leads us to inquire whether the female, when grown up, has not less of the true female character than other women, and is incapable of having children." "It is curious," says Sir Everard, "and in some measure to the purpose, that, in some countries, nurses and midwives have a prejudice, that such twins seldom breed." The remark of Sir Everard is signally unfortunate, and ought not to have been hastily hazarded, seeing that a slight examination would have exhibited that there is no analogy between the free-martin and the females in question; and, more especially, as the suggestion accords with a popular prejudice, highly injurious to the prospects and painful to the feelings of all who are thus situated. In the *London Medical Repository*, for September, 1823, Mr. Cribb, of Cambridge, England, has properly observed, that the external characters and anatomical conformation of the free-martin are totally unlike those of the human female. In external appearance, the free-martin differs considerably from the perfectly formed cow, the head and neck, in particular, bearing a striking resemblance to those of the bull. Mr. Cribb has, however, brought forward the most decisive evidence in favour of the fallacy of the popular prejudice, by the history of seven cases, which are of themselves sufficient to put the matter for ever at rest. Of these *seven* cases,—which are all that he had ever known, of women, born under the circumstances in question, having been married,—*six* had children.

Before proceeding to the physiology of generation, there is one function, peculiar to the female, which will require consideration. This consists in a periodical discharge of blood from the vulva, occurring from three to six days in every month, during the whole time that the female is capable of conceiving, or from the period of puberty to what has been termed the *critical age.* This discharge is called the *catamenia*, *menses*, *flowers*, &c., and the process *menstru-*

ation. It seems to be possessed by the human species alone. F. Cuvier, however, asserts that he has discovered indications of it in the females of certain animals.

In some females, menstruation is established suddenly, and without any premonitory symptoms; but, in the greater number, it is preceded and accompanied by some inconvenience. The female complains of signs of plethora, or general excitement,—indicated by redness and heat of skin, heaviness in the head, oppression, quick pulse, and pains in the back or abdomen; whilst the discharge commences drop by drop, but continuously.

During the first twenty-four hours, the flow is not as great as afterwards, and is more of a serous character; but, on the following day, it becomes more abundant and sanguineous, and gradually subsides, leaving, in many females, a whitish, mucous discharge, technically termed *leucorrhœa*, and, in popular language, the *whites*.

The quantity of fluid, lost during each menstruation, varies greatly, according to the individual and to the climate. Its average is supposed to be from six to eight ounces in temperate climes. By some, it has been estimated as high as twenty, but this is an exaggeration.

The menstrual fluid proceeds from the interior of the uterus, and not from the vagina. At one time, it was believed, that in the intervals between the flow of the menses, the blood gradually accumulates in some parts of the uterus, and when these parts attain a certain degree of fulness, they give way and the blood flows. This office was ascribed to the cells,—which were conceived to exist in the substance of the uterus between the uterine arteries and veins,—and, by some, to the veins themselves, which, owing to their great size, were presumed to be reservoirs, and hence were called *uterine sinuses*.

The objection to these views is,—that we have no evidence of the existence of any such accumulation; and that when the interior of the uterus of one, who has died during menstruation, is examined, there are no signs of any such rupture as that described; whilst the enlarged vessels exist only during pregnancy or during the expanded state of the uterus; the veins, in the unimpregnated uterus, being extremely small, and totally inadequate for such a purpose.

The menstrual fluid is a true exhalation, effected from the inner surface of the uterus. This is evident from the change in the lining membrane of the organ during the period of its flow. It is rendered softer and more villous, and exhibits bloody spots, with numerous pores from which the fluid may be expressed. An injection, sent into the arteries of the uterus, also readily transudes through the lining membrane. The appearance of the menstrual fluid in the cavity of the uterus, during the period of its flow; its suppression in various morbid conditions of the organ; and the direct evidence, furnished to Ruysch, Blundell, Clarke, and others, in cases of prolapsus or of inversio uteri, where the fluid has been seen distilling from the uterus, likewise show that it is a uterine exhalation.

It has been a question, whether the fluid proceeds from the arteries or veins; and this has arisen from the circumstance of its being regarded as mere blood, which it is not. It is in truth but little like blood, except in colour; and it may be distinguished from blood by the smell, which is *sui generis*, and also by its not being coagulable. "It is," says Mr. Hunter, "neither similar to blood taken from a vein of the same person, nor to that which is extravasated by accident in any other part of the body; but is a species of blood, changed, separated, or thrown off from the common mass by an action of the vessels of the uterus, similar to that of secretion, by which action the blood loses the principle of coagulation and, I suppose, life." The principle of coagulation does not exist, owing to absence of the due quantity of fibrine. (Lavagna.) The fluid has the properties, according to Brande, of a very concentrated solution of the colouring matter of the blood in a diluted serum.

The fact of the injection, sent into the arteries, transuding through the inner lining of the uterus is in favour of the exhalation taking place from the arteries, and the analogy of all the other exhalations is confirmatory of the position.

The efficient cause of menstruation has afforded ample scope for speculation and hypothesis. As its recurrence corresponds to a revolution of the moon around the earth, lunar influence has been invoked; but, before this solution can be admitted, it must be shown, that the effect of lunar attraction is different in the various relative positions of the moon and earth. There is no day of the month, in which numerous females do not commence their menstrual flux, and, whilst the discharge is beginning with some, it is at its acme or decline with others. The hypothesis of lunar influence must therefore be rejected.

In the time of Van Helmont, it was believed, that a ferment exists in the uterus, which gives occasion to a periodical, intestine motion in the vessels, and a recurrence of the discharge; but independently of the want of evidence of the existence of such a ferment, the difficulty remains of accounting for its regular renovation every month.

Local and general plethora have been assigned as causes, and many of the circumstances, that modify the flow, favour the opinion. The fact of, what has been called, *vicarious menstruation*, has been urged in support of this view. In these cases, instead of the menstrual flux taking place from the uterus, hemorrhages occur from various other parts of the body, as the breasts, lungs, ears, eyes, nose, &c. It does not seem, however, that in any of these cases, the term *menstruation* is appropriate; inasmuch as the fluid is not menstrual, but consists of blood periodically extravasated. Still, they would appear to indicate, that there is a necessity for the monthly evacuation, or *purgations*, as the French term it; and that if this be obstructed, a vicarious hemorrhage may be established; yet the loss of several times the quantity of blood from the arm, previous to, or

in the very act of, menstruation does not always prevent or interrupt the flow of the catamenia; and in those maladies, which are caused by their obstruction, greater relief is afforded by the flow of a few drops from the uterus itself, than by ten times the quantity from any other part.

Some of the believers in local plethora of the uterus have maintained, that the arteries of the pelvis are more relaxed in the female than in the male; whilst the veins are more unyielding; and hence, that the first of these vessels convey more blood than the second return. It has been also affirmed, that whilst the arteries of the head predominate in man, by reason of his being more disposed for intellectual meditation; the pelvic and uterine arteries predominate in the female, owing to her destination being more especially for reproduction.

Setting aside all these gratuitous assumptions, it is obvious, that a state, if not of plethora, at least of irritation, must occur in the uterus every month, which gives occasion to the menstrual secretion; but, as Adelon has properly remarked, it is not possible to say, why this irritation is renewed monthly, any more than to explain, why the predominance of one organ succeeds that of another in the succession of ages. The function is as natural, as instinctive to the female, as the developement of the whole sexual system at the period of puberty. That it is connected most materially with the capability of reproduction is shown by the fact, that it does not make its appearance until puberty,—the period at which the young female is capable of conceiving,—and that it disappears at the critical time of life, when conception is impracticable. It is arrested, too, as a general rule, during pregnancy and lactation; and in amenorrhœa or obstruction of the menses, fecundation is not readily effected. In that variety, indeed, of menstruation, which is accomplished with much pain at every period, and is accompanied by the secretion of a membranous substance having the shape of the uterine cavity, conception may be esteemed impracticable. Professor Hamilton, of the University of Edinburgh, has been in the habit of adducing this, in his lectures, as one of two circumstances—the other being the want of a uterus—which are invincible obstacles to fecundation. Yet, in the case of dysmenorrhœa, of the kind mentioned, if the female can be made to pass one monthly period without suffering, or without the morbid secretion from the uterine cavity, she will sometimes become pregnant, and the whole of the evil will be removed: for, the effect of pregnancy being to arrest the catamenia, the morbid habit is usually got rid of during gestation and lactation, and does not subsequently recur.

Gall strangely supposed, that some general, but extraneous cause of menstruation exists,—not the influence of the moon; and he affirms, that, in all countries, females generally menstruate about the same time: that there are, consequently, periods of the month in which none are in that condition; and he affirms, that all

females may, in this respect, be divided into two classes:—the one comprising those who menstruate in the first eight days of the month, and the other, those who are "unwell"—as it is termed by them, in some countries—in the last fortnight. He does not, however, attempt to divine what this cause may be. We are satisfied that his positions are erroneous. Attention to the matter has led us to the belief, already expressed, that there is no period of the moon, at which the catamenial discharge is not taking place in some; and we have not the slightest reason for supposing, that, on the average, more females are menstruating at any one part of the month than at another.

After these comments, it is unnecessary to notice the visionary speculations of those, who have regarded menstruation as a mechanical consequence of the erect attitude; or the opinion of Roussel, that it originally did not exist, but that being produced artificially by too succulent a regimen, it was afterwards propagated from generation to generation; or, finally, that of Aubert, who maintained, that if the first amorous inclinations were satisfied, the resulting pregnancy would totally prevent the establishment of menstruation. The function, it need scarcely be repeated, is instinctive, and forms an essential part of the female constitution.

The age, at which menstruation commences, varies in individuals and in different climates. It is a general law, that the warmer the climate, the earlier the discharge takes place, and the sooner it ceases. In some climates, it begins at nine years of age, whilst in northern regions, women may not arrive at puberty until they are seventeen or eighteen years old. In the temperate zone, the most common period is from thirteen to fifteen years. Menstruation commonly ceases in the same zone at from forty to fifty years. In oriental climes, the menses begin soon, flow copiously, and end early;—females being old when those of the temperate regions would be still in their prime. In northern regions, on the contrary, they begin late, flow sparingly, and continue long.

These estimates are, however, liable to many exceptions. The menses, with powers of fecundity, have continued, in particular instances, much beyond the ages that have been specified; some of these protracted cases having had regular catamenia; in others, the discharge, after a long suppression, having returned. A relation of Haller had two sons after her fiftieth year; and children are said to have been born, even after the mother had attained the age of sixty. Holdefreund relates the case of a female, in whom menstruation continued till the age of seventy-one; Bourgeois till the age of eighty; and Hagendorn till ninety; however, it is probable, that these were not cases of true menstruation, but perhaps of irregularly periodical discharges of true blood from the uterus or vagina.

As a general rule, the appearance of the menses denotes the capability of being impregnated, and their cessation the loss of such capability. Yet, females have become mothers without ever having

menstruated. Fodéra attended a woman, who had menstruated but once—in her 17th year—although 35 years of age, healthy, and the mother of five children. Morgagni instances a mother and daughter, both of whom were mothers before they menstruated. Sir E. Home mentions the case of a young woman, who was married before she was 17, and, having never menstruated, became pregnant; four months after her delivery, she became pregnant again; and four months after the second delivery, she was a third time pregnant, but miscarried. After this, she menstruated for the first time, and continued to do so for several periods, when she again became pregnant;—yet, Dr. Dewees and Dr. Campbell assert, that there is not a properly attested instance on record, of an individual conceiving previous to the establishment of the catamenia; the latter gentleman admits, however, that when an individual has once been impregnated, she may conceive again, several times in succession, without any recurrence of the catamenia between these different conceptions,—because *he* has known a case of this kind, but not of the other!

During the existence of menstruation, the system of the female is more irritable than at other times; so that all exposure to sudden and irregular checks of transpiration should be avoided, as well as every kind of mental and corporeal agitation, otherwise the process may be impeded, or hysterical and other troublesome affections be excited. The sacred volume exhibits the feeling entertained towards the female, whilst performing this natural function. Not only was she regarded 'unclean' in antiquity; she was looked upon, as Dr. Elliotson has remarked, as mysteriously deleterious. In the time of Pliny, a female, during menstruation, was considered to blight corn, destroy grafts and hives of bees, dry up fields of corn, cause iron and copper to rust and smell, drive dogs mad, &c. &c.; and Dr. Elliotson says it is firmly believed by many, in England, that meat will not take salt if the process be conducted by a female so circumstanced.

Physiology of Generation.

In man and the superior animals, in which each sex is possessed by a distinct individual, it is necessary that there should be a union of the sexes, and that the fecundating fluid of the male should be conveyed within the appropriate organs of the female; in order that, from the concourse of the matters furnished by both sexes, a new individual may result.

To this union we are incited by an imperious instinct, established within us for the preservation of the species; as the senses of hunger and thirst are placed within us for the preservation of the individual. This has been termed the *desire* or *instinct of reproduction;* and, for wise purposes, its gratification is attended with the most pleasurable feelings, which man or animals can experience.

Prior to the period of puberty, or whilst the individual is incapable of procreation, this desire does not exist; but it suddenly makes its appearance at puberty, persists vehemently during youth and the adult age, and disappears in advanced life, when procreation becomes again impracticable. It is strikingly exhibited in those animals, in which generation can only be effected at particular periods of the year, or whilst they are in *heat*;—as in the deer, during the *rutting* season.

false

The views, which have been entertained, regarding the seat of this instinct—whether in the encephalon or genital organs—were considered under the head of the mental and moral manifestations. It was there stated, that Cabanis and Broussais make the internal impressions to proceed from the genital organs, but to form a part of the psychology of the individual; and that Gall assigns an encephalic organ—the cerebellum—for its production, and ranks the instinct of reproduction amongst the primary faculties of the mind. In farther proof of the idea, which refers it to the encephalon, it may be remarked, that the instinct has been observed in those, who, owing to original malformation, have wanted the principal part of the genital organs, whilst it has continued, in the case of eunuchs not castrated till after the age of puberty.

In opposition to this view, it has been urged, that simple titillation of the organs will excite the desire. This, however, may be entirely dependent upon association, in which the brain is largely concerned. In many cases, the desire is produced through the agency of vision; when the brain must necessarily be first excited, and, through its influence, the generative apparatus.

The cause of the desire has, by some, been ascribed to the presence of sperm, in the requisite quantity, in the vesiculæ seminales; but, in answer to this, it is urged, that eunuchs, under the circumstances abovementioned, and females, in whom there is no spermatic secretion, have the desire.

The fact is, we have no more precise knowledge of the nature of this instinct, than we have of any of the internal sensations or moral faculties. We know, however, that it exhibits itself in various degrees of intensity, and occasionally assumes an opposite character—constituting *anaphrodisia*.

In the union of the sexes, the part performed by the *male* is the introduction of the penis,—the organ for the conveyance of the sperm to the uterus,—and the excretion of that fluid, during its introduction. In the flaccid state of the organ, this penetration is impracticable; it is first of all necessary, that, under the excitement of the venereal desire, the organ should attain a necessary state of rigidity, which is termed *erection*. In this state, the organ becomes enlarged, and raised towards the abdomen; its arteries beat forcibly; the veins become tumid; the skin more coloured, and the heat aug-

mented. It becomes also of a triangular shape, and these changes are indicated by an indescribable feeling of pleasure.

Erection is not dependent upon volition. At times, it manifests itself against the will; at others, it refuses to obey it; yet it requires, apparently, the constant excitement of the encephalic organ concerned in its production;—the slightest distraction of the mind causing its cessation. The modest and retiring spouse is, at times, unable to comsummate the marriage for nights, perhaps weeks; yet, he is only temporarily impotent; for the inclination and the consequent erection supervene sooner or later. Pills of the crumb of bread, and a recommendation to the individual not to approach his wife for a fortnight, whatever may be his desire, have, in almost all cases, removed the impotence.

The state of erection is not long maintained, except under unusual excitement; the organ soon returning to its ordinary flaccidity. Its cause is a congestion of blood in the erectile tissue of the corpora cavernosa, urethra, and glans. Swammerdam and De Graaf cut off the penis of a dog during erection, and found the tissue gorged with blood, and that the organ returned to its flaccid condition, as the blood flowed from it. The same fact, according to Adelon, has been observed in the human subject, where erection has continued till after death. Mr. Callaway, of Guy's Hospital, London, has described the case of an individual, who, in a state of inebriation, had communication three times with his wife the same night, without the consequent collapse succeeding, although emission ensued each time. This condition persisted for sixteen days, notwithstanding the use of the appropriate means: at this time, an opening was made with a lancet into the left crus of the penis, below the scrotum, and a large quantity of dark, grumous blood, with numerous small coagula, escaped. By pressing the penis, the corpora cavernosa were immediately emptied, and each side became flaccid; the communication by the pecten, or septum penis permitting the discharge of the contents of both corpora by the incision into the left crus. After recovery, the person remained quite impotent, the organ being incapable of erection, probably owing, as Mr. Callaway suggests, to the deposition of coagulable lymph in the cells of the corpora cavernosa preventing the admission of blood, and the consequent distention of the organ.

Artificial erection can, likewise, be induced in the dead body by injections, so that but little doubt need exist, that the enlargement and rigidity of the penis, during erection, are caused by the larger quantity of blood sent into it.

The great difficulty has been, to account for this increased flow. The older writers ascribed it to the compression of the internal pudic vein against the symphysis pubis, owing to the organ being raised towards the abdomen by the ischio-cavernosi muscles; and as the cavernous vein empties its blood into the internal pudic, stagnation of blood in the corpora cavernosa ought necessarily to result

from such compression, and consequent distention of the organ; whilst the cavernous arteries, being firmer, would not yield to the compression, and would, therefore, continue to convey the blood to the penis.

It is obvious, however, that here,—as in every case, where the erectile tissue is concerned,—the congestion must be of an active kind: the beating of the arteries and the coloration of the organ indicate this; and, besides, compression of the pudic vein cannot precede erection; it must, if it occur at all, be regarded rather as a consequence of erection than as its cause. The case of the female nipple affords us an instance of erectility, where no compression can be invoked, and where the distention must be caused by augmented flow of blood by the arteries. If the nipple be handled, particularly whilst the female is under voluptuous excitement, it will be found to enlarge, and to become rigid, or to be in a true state of erection. The correct opinion is, that irritation of this erectile tissue is the first link in the chain of phenomena constituting erection. The feeling of pleasure is certainly experienced there, prior to, and during, erection; and this irritation, like every other, solicits an increased flow of blood into the erectile tissue, which, by organization, is capable of considerable distention.

The erectile tissues of the corpora cavernosa, and of the corpus spongiosum urethræ, and glans, are all concerned in the process; but, in what precise manner, physiologists are not entirely agreed. Some have supposed, that the blood is effused into the cells, and is consequently out of the vessels. Another view, supported by some of the most eminent anatomists and physiologists is, that the blood simply accumulates in the venous plexuses of the corpora cavernosa. Such seems to have been the inference of Cuvier, Chaussier, and Béclard, from their injections; and the rapidity, with which erection disappears, favours the notion.

It has been asked, again, whether this accumulation of blood be, as we have remarked, an increased afflux by the arteries, or a diminished action of the veins; or these two states combined. The last opinion is probably the most correct. The arteries first respond to the appeal; the organ is, at the same time, raised by the appropriate muscles; its tissue becomes distended, the plexus of veins turgid, and the return of blood impeded. In this way, the organ acquires the rigidity, necessary for penetrating the parts of the female. The friction, which then occurs, keeps up the voluptuous excitement and the state of erection. This excitement is extended to the whole generative system; the secretion of the testicle is augmented; the sperm arrives in greater quantity in the vesiculæ seminales; the testicles are drawn up towards the abdominal rings by the contraction of the dartos and cremaster, so that the vas deferens is rendered shorter, and, in the opinion of some, the sperm, filling the excretory ducts of the testicle, is, in this manner, forced mechanically forwards towards the vesicles. When these have attained a

certain degree of distention, they contract suddenly and powerfully, and the sperm is projected through the ejaculatory ducts into the urethra. At this period, the pleasurable sensation is at its height. When the sperm reaches the urethra, the canal is thrown into the highest excitement; the ischio-cavernosi and bulbo-cavernosi muscles, with the transversus perinei, and levator ani, are thrown into violent contraction; the two first holding the penis straight, and assisting the others in projecting the sperm along the urethra. By the agency of these muscles and of the proper muscular structure of the urethra, the fluid is expelled, not continuously, but in jets, as it seems to be sent into the urethra by the alternate contractions of the vesiculæ seminales.

The quantity of sperm, discharged, varies materially according to the circumstances previously mentioned; its average is estimated at about two drachms.

Along with the true sperm, the fluids of the prostate and of the glands of Cowper are discharged; so as to constitute the semen as we meet with it. When the emission is accomplished, the penis gradually returns to its ordinary state of flaccidity; and it is usually impracticable, by any effort, to repeat the act without the intervention of a certain interval of repose, to enable the due quantity of sperm to collect in the spermatic vessels and vesicles. In some persons, however, the excitability is so great, and the secretion of sperm so ready, that little or no interval is required between the first and second attempt.

This comprises the whole of the agency of the male in the function of generation.

In man, the emission of sperm is soon effected; but in certain animals it is a long process. In the dog, which has no vesiculæ seminales, the penis swells so much, during copulation, that it cannot be withdrawn until the emission of sperm removes the erection.

In the *female*, during copulation, the clitoris is in the same state of erection as the penis; as well as the spongy tissue, lining more especially the entrance of the vagina; and it is in these parts, particularly in the clitoris, that pleasure is experienced during sexual desire, and during copulation. This feeling persists the whole time of coition, and ultimately attains its acme, as in the case of the male, but without any spermatic ejaculation. It is not owing to the contact of the male sperm,—for it frequently occurs before or after emission by the male, but is dependent upon some inappreciable modification in the female organs,—in the ovaries or Fallopian tubes, it is supposed by some physiologists. In most cases, an increased discharge suddenly takes place, during the orgasm, from the mucous follicles of the vagina and vulva. After the kind of convulsive excitement into which the female is thrown, a sensation of languor and debility is experienced, as in the male, but not to the same extent,—and, in consequence of no spermatic emission taking place in her, she is ca-

pable of a renewal of intercourse more speedily than the male, and can better support its frequent repetition.

An admixture having, in this manner, been effected between the materials furnished by the male and those of the female; after a fecundating copulation *conception* or *fecundation* results, and the rudiments of the new being are instantaneously constituted. The well-known fact, that, after the removal of the testicles, the individual is incapable of procreation, although the rest of the genital organs may remain entire, is of itself sufficient to show, that the fecundating fluid is the secretion of those organs, and that this fluid is indispensable. Physiologists have not, however, been satisfied with this fact. Spallanzani examined frogs with great attention, whilst in the act of copulation, both in and out of water; and he observed, that, at the moment when the female deposited her eggs, the male darted a transparent liquor through a tumid point which issued from its anus. This liquor moistened the eggs, and fecundated them. To be certain that it was the fecundating agent, he dressed the male in waxed taffeta breeches; when he found, that fecundation was prevented, and that sperm enough was contained in the breeches to be collected. This he took up by means of a camel's-hair pencil, and all the eggs, which he touched with it, were fecundated. Three grains of this sperm were sufficient to render a pound of water fecundating; and a drop of this solution, which could not contain more than the 2,994,687,500th part of a grain was enough for the purpose.

To diminish the objection, that the frog is too remote in organization from man to admit of any analogical deduction, Spallanzani took a spaniel bitch, which had engendered several times; shut her up some time before the period of *heat*, and waited until she exhibited evidences of being in that condition, which did not happen until after a fortnight's seclusion. He then injected into the vagina and uterus, by means of a common syringe warmed to 100° of Fahrenheit, nineteen grains of sperm obtained from a dog. Two days afterwards she ceased to be in heat, and, at the ordinary period, she brought forth three young ones, which not only resembled her but the dog from which the sperm had been obtained. This experiment has been repeated by Rossi, of Pisa, and by Buffolini, of Cesena, with similar results. The success of an analogous experiment on the human species rests on the authority of John Hunter. He recommended an individual, affected with hypospadias, to inject his sperm by means of a warm syringe. His wife afterwards became pregnant.

In some experiments on generation, Prévost and Dumas fecundated artificially the ova of the frog. Having expressed the fluid from several testicles, and diluted it with water, they placed the ova in it. These were observed to become tumid and developed; whilst other ova, placed in common water, merely swelled up, and in a few

days became putrid. They observed, moreover, that the mucus, with which the ova are covered in the *oviduct*,—the part corresponding to the Fallopian tube in the mammalia,—assists in the absorption of the sperm, and in conducting it to the surface of the ovum; and that, in order to succeed in these artificial fecundations, the sperm must be diluted. If too much concentrated its action is less. They satisfied themselves, likewise, that the chief part of the sperm penetrates as far as the ova, as animalcules could be detected moving in the mucus covering their surface, and these animalcules they conceive to be the active part of the sperm.

It is not, however, universally admitted, that the positive contact of the sperm with the ovum is indispensable to fecundation. Some physiologists maintain, that the sperm proceeds no farther than the upper part of the vagina; whence it is absorbed by the vessels of that canal, and conveyed through the circulation to the ovary. This is, however, the most improbable of all the views that have been indulged on this topic; for if such were the fact, impregnation ought to be effected as easily by injecting sperm into the blood-vessels,—the female being, at the time, in a state of voluptuous excitement. It has been directly overthrown, too, by the experiments of Dr. Blundell on the rabbit, who found, that when the communication betwen the vagina and the uterus was cut off, impregnation could not be accomplished, although the animal admitted the male as many as fifty times, generally at intervals of two or three days or more. Yet, it is evident—Dr. Blundell remarks—that much of the male fluid must have been deposited in the vagina, and absorbed by the veins or lymphatics. Others have presumed, that when the sperm is thrown into the vagina, a *halitus* or *aura*—the *aura seminis*—escapes from it, makes its way to the ovary, and impregnates an ovum. Others, again, think that the sperm is projected into the uterus, and that in this cavity it undergoes admixture with the germ furnished by the female; whilst a last class, with more probability in their favour, maintain that the sperm is thrown into the uterus, whence it passes through the Fallopian tube to the ovary, the fimbriated extremity of the tube, at the time, embracing the latter organ.

Dr. Dewees,—the able professor of midwifery in the University of Pennsylvania,—has suggested, that after the sperm is deposited on the labia pudendi or in the vagina, it may be taken up by a set of vessels—which, he admits, have never been seen in the human female—whose duty it is to convey the sperm to the ovary. This conjecture he conceives to have been in part confirmed, by the discovery of ducts, leading from the ovary to the vagina, in the cow and sow, by Dr. Gartner, of Copenhagen. The objections that may be urged against his hypothesis, Dr. Dewees remarks, "he must leave to others." We have no doubt, that his intimate acquaintance with the subject could have suggested many that are pertinent and cogent. It will be obvious, that if we admit the existence of the

ducts, described by Gartner, it by no means follows, that they are certainly inservient to the function in question. Independently, too, of the objection, that they have not been met with in the human female, it may be urged, that if we grant their existence, there would seem to be no reason, why closure of the os uteri after impregnation, or interruption of the vulvo-uterine canal, by division of the vagina—as in the experiments of Dr. Blundell on rabbits, or division of the Fallopian tubes, should prevent subsequent conception, in the first case during the existence of pregnancy; in the two last, for life. These vessels ought, in both cases, to continue to convey sperm to the ovary, and extra-uterine pregnancies or superfœtation ought to be constantly occurring.

MM. Prévost and Dumas are the most recent writers, who maintain, that fecundation takes place in the uterus, and they assign the following reasons for their belief. *First.* That in their experiments, they always found sperm in the cornua of the uterus, and they conceive it natural, that fecundation should be operated only where sperm is. *Secondly.* That in those animals, whose ova are not fecundated until after they have been laid, fecundation must necessarily be accomplished out of the ovary; and *Thirdly,* that in their experiments on artificial fecundation, they have never been able to fecundate ova taken from the ovary.

In reply to the first of these positions it has been properly remarked by Adelon, that the evidence of MM. Prévost and Dumas, with regard to the presence of sperm elsewhere than in the uterus, is only of a negative character; and that, on the other hand, we have the positive testimony of physiologists in favour of its existence in the Fallopian tubes and ovary. Haller asserts, that he found it there; and MM. Prévost and Dumas afford us evidence against the position they have assumed respecting the seat of fecundation. They affirm, that on the first day after copulation, the sperm was discoverable in the cornua of the uterus, and that it was not until after the lapse of twenty-four hours, that it had attained the summits of the cornua. Once they detected it in the Fallopian tubes:—a circumstance which is inexplicable under the view, that fecundation is accomplished in the uterus. Leeuenhoek and Hartsöker also found it in some cases in the Fallopian tube.

In reply to the second argument it may be remarked, that analogies drawn from the inferior animals are frequently very loose and unsatisfactory, and ought consequently to be received with caution. This is peculiarly one of these cases; for fecundation, in the case adduced, is always accomplished *out* of the body, and analogy might with equal propriety be invoked to prove, that in the human female fecundation must also be effected externally.

In answer to the third negative position of MM. Prévost and Dumas, the positive experiments of Spallanzani may be adduced, who succeeded in producing fecundation in ova, that had been previously separated from the ovary.

The evidence, that conception takes place in the ovary, appears, to us convincing. The cases of ovarian pregnancy offer irresistible proof. Of these Mr. Stanley of Bartholomew's Hospital has given an instructive example in the sixth volume of the *Medical Transactions;* and a still more extraordinary instance is related by Dr. Granville in the *Philosophical Transactions* for 1820. Other varieties of extra-uterine pregnancy are confirmative of the same position. At times, the fœtus is found in the cavity of the abdomen,—the ovum seeming to have escaped from the Fallopian tube when its fimbriated extremity grasped the ovary to receive the ovum and convey it to the cavity of the uterus. At other times, the fœtus is developed in the Fallopian tube,—as in the marginal figure,—some impediment having existed to the passage of the ovum from the ovarium to the uterus. This impediment can, indeed, be excited artificially so as to give rise to tubal pregnancy. Nuck applied a ligature around one of the cornua of the uterus of a bitch, three days after copulation; and he found, afterwards, two fœtuses arrested in the Fallopian tube between the ligature and the ovary. Moreover, Raspail asserts, that he once met with an ovule, still attached to the ovary, which contained an embryo.

Fig. 153.

Tubal pregnancy.

It is obvious, then, from these facts, either that fecundation occurs in the ovarium, or else that the ovum, when fecundated in the uterus, travels along the Fallopian tube to the ovarium, and from thence back again to the uterus, which is not probable. Moreover, that the ovaries are indispensable agents in the function of generation is shown by the well-known fact, that their removal, by the operation of *spaying*, not only precludes reproduction but takes away all sexual desire. In the *Philosophical Transactions* for 1805, a case is detailed of a natural defect of this kind in an adult woman, who had never exhibited the slightest desire for commerce with the male, and had never menstruated. On dissection, the ovaria were found deficient; and the uterus was not larger than an infant's.

But, to prevent impregnation, it is not even necessary that the ovaries should be removed. It is sufficient to deprive them of all immediate communication with the uterus, by simply dividing the Fallopian tubes. On this subject, Haighton instituted numerous experiments, the result of which was, that after this operation, a fœtus was in no instance produced. The operation is much more simple than the ordinary method of spaying by the removal of the ovaries, and it has been for several years successively practised, at

the recommendation of the author, on the farm of his friend Mr. Jefferson Randolph, of Virginia. It does not seem that the simple division of the Fallopian tubes takes away the sexual desire, as Haighton supposed. Dr. Blundell has proposed this division of the tubes, and even the removal of a small portion of them, so as to render them completely impervious, when the pelvis is so contracted as not to admit of the birth of a living child in the seventh month; and he goes so far as to affirm, that the operation is much less dangerous than delivery by perforating the head, when the pelvis is greatly contracted.

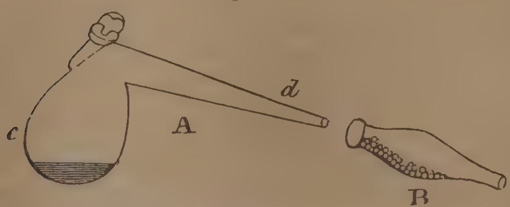
We have already remarked, that sperm has been found in the cavity of the uterus, and even in the Fallopian tubes. Fabricius ab Acquapendente maintained that it could not be detected there; and Harvey contended, that, in the case of the cow, whose vagina is very long, as well as in numerous other animals, the sperm cannot possibly reach the uterus, and that there is no reason for supposing that it ever does. In addition, however, to the facts already cited, we may remark, that Mr. John Hunter killed a bitch in the act of copulation, and found the semen in the cavity of the uterus, conveyed thither, in his opinion, *per saltum.* Ruysch discovered it in the uterus of a woman taken in adultery by her husband and killed by him; and Haller in the uterus of a sheep killed forty-five minutes after copulation. Recently, an interesting case, in relation to this point, has been published by Dr. H. Bond, of Philadelphia. A young female, after having passed a part of the night with a male friend, destroyed herself early in the morning, by taking laudanum. On cutting open the uterus, it was found to be thickly coated with a substance having the appearance, and the strong peculiar odour, of the sperm. One of the Fallopian tubes was laid open, and found to contain, apparently, the same matter, but it was not ascertained whether it possessed the seminal odour.

Blumenbach supposes, that, during the venereal orgasm, the uterus sucks in the sperm. It is impossible to explain the mode in which this is accomplished, but the fact of the entrance of the fluid into the uterus, and even as far as the ovarium, seems unquestionable. This Dr. Blundell admits, but he is disposed to think, that, in general, the rudiments from the mother, and the fecundating fluid meet in the uterus; as, in his experiments on rabbits, he found—from the formation of corpora lutea, the developement of the uterus and the accumulation of water in the uterine cavity—that the rudiments may come down into the uterus, without a previous contact of the semen. His experiments, however, appear to us to prove nothing more, than that infecund ova may be discharged from the ovarium, and that if they are prevented from passing externally, owing to closure of the vagina or cervix uteri, the uterine phenomena, alluded to, may occur. They do not invalidate the arguments already adduced to show, that the ovum must be fecundated in the ovarium.

Granting, then, that conception occurs in the ovarium, and that sperm is projected into the uterus, with or without the action of aspiration referred to by Blumenbach, in what manner does the sperm exert its fecundating agency on the ovarium? It is manifestly impossible, that the force of projection from the male can propel it, not only as far as the cornua of the uterus, but also through the narrow media of communication between the uterus and ovary by the Fallopian tubes. This difficulty suggested the idea of the *aura seminis* or *aura seminalis*, which, it was supposed, might readily pass into the uterus, and through the tubes to the ovary. Haighton, indeed, embraced an opinion more obscure than this, believing that the semen penetrates no farther than the uterus, and acts upon the ovaria by sympathy; and this view has been adopted by some distinguished individuals.

In opposition to the notion of the *aura seminis*, we have some striking facts and experiments. In all those animals, in which fecundation is accomplished out of the body, direct contact of the sperm appears necessary. Spallanzani, and MM. Prévost and Dumas found, in their experiments on artificial fecundation, that they were always unsuccessful when they simply subjected the ova to the emanation from the sperm. Spallanzani took two watch-glasses, capable of being fitted to each other, the concave surface of the one being opposed to that of the other. Into the lower he put ten or twelve grains of sperm, and into the upper about twenty ova. In the course of a few hours, the sperm had evaporated, so that the ova were moistened by it; yet they were not fecundated, but fecundation was readily accomplished by touching them with the sperm that remained in the lower glass. A similar experiment was performed by MM. Prévost and Dumas. They prepared about an ounce and a half of a fecundating fluid from the expressed humour of twelve testicles, and as many vesiculæ seminales. With two and a half drachms of this fluid they fecundated more than two hundred ova. The remainder of the fluid was put into a small retort, to which an adopter was attached. In this, forty ova were placed, ten of which occupied the hollowest part, whilst the rest were placed near the beak of the retort. The apparatus was put under the receiver of an air-pump, and air sufficient was withdrawn to diminish the pressure of the atmosphere one-half. The rays of the sun were now directed upon the body of the retort, until the temperature within rose to about 90°: after the lapse

Fig. 154.



A. The retort containing the sperm.—B. The adopter containing the ova.—*c*. Body of the retort.—*d*. Beak of the retort.

of four hours, the experiment was stopped, when the following were the results. The eggs, at the bottom of the adopter, were bathed in a transparent fluid, the product of distillation. They had become tumid as in pure water, but had undergone no developement. The eggs, near the beak of the retort, were similarly circumstanced, but all were readily fecundated by the thick sperm, which remained at the bottom of the retort. No aura, no emanation from the sperm consequently appeared to be capable of impregnating the ova. Absolute contact was indispensable.

This is probably the case with the human female, and if so, the sperm must proceed from the uterus along the Fallopian tube to the ovarium. The common opinion is, that during the intense excitement at the time of copulation, the tube is raised, and its digitated extremity applied to the ovarium. The sperm then proceeds along it,—in what manner impelled we know not,—and attains the ovary. According to Blundell and others, during the time of intercourse, the whole of the tube is in a state of spontaneous movement. Cruikshank pithed a female rabbit, when in heat, and examined the uterine system very minutely. The external and internal parts of generation were found black with blood; the Fallopian tubes were twisted like writhing worms, and exhibited a very vivid peristaltic motion, and the fimbriæ embraced the ovaria, like fingers laying hold of an object, so closely and so firmly as to require some force, and even slight laceration to disengage them. Haller states, that by injecting the vessels of the tube in the dead body, it has assumed this kind of action. De Graaf, too, affirms, that he has found the fimbriated extremity adhering to the ovary, twenty-seven hours after copulation; and Magendie, that he has seen the extremity of the tube applied to a vesicle.

As the aura seminis appears to be insufficient for impregnation, it is obviously a matter of moment, that the sperm should be ejaculated as high up into the vagina as possible. It has been often observed, that where the orifice of the urethra does not open at the extremity of the glans, but beneath the penis, or at some distance from the point, the individual has been rendered less capable of procreation. In a case, that fell under the care of the author, the urethra was opened opposite the corona glandis by a sloughing syphilitic sore, and the aperture continued, in spite of every effort to the contrary. The individual was married, and the father of three or four children; but after this occurrence he had no increase of his family. Many medico-legal writers have considered, that when the urethra terminates at some other than its natural situation, impotence is the necessary result,—that although copulation may be effected, impregnation is impracticable. Zacchias, however, gives a positive case to the contrary. Belloc, too, asserts, that he knew a person, in whom the orifice of the urethra terminated at the root of the frænum, who had four children that resembled the father, two having the same malformation; and Dr. Francis refers to the case of an inhabitant of

New York, who, under similar circumstances, had two children. We cannot, therefore, regard it as an absolute cause of impotence, but the inference is just, that if the semen be not projected far up into the vagina, and in the direction of the os uteri, impregnation is not likely to be accomplished; a fact, which it might be of moment to bear in mind, where the rapid succession of children is an evil of magnitude.

The part, then, to which the semen is applied is the ovary. Let us now inquire into the changes experienced by this body after a fecundating copulation.

Fabricius ab Acquapendente, having killed hens a short time after they had been trodden, examined their ovaries, and observed,—amongst the small yellow, round, granula, arranged racemiferously, which constitute those organs,—one having a small spot, in which vessels became developed. This increased in size, and was afterwards detached, and received by the oviduct; becoming covered, in its passage through that tortuous canal and the cloaca, by particular layers, especially by the calcareous envelope; and being ultimately extruded in the form of an egg. Harvey, in his experiments on the doe, made similar observations. He affirms, positively, that the ovary furnishes an ovum, and that the only difference, which exists amongst animals in this respect, is, that, in some, the ovum is hatched after having been laid, whilst, in others, it is deposited in a reservoir —a womb—where it undergoes successive changes.

De Graaf instituted several experiments on rabbits, for the purpose of detecting the series of changes in the organs from conception till delivery. Half an hour after copulation, no alteration was perceptible, except that the cornua of the uterus appeared a little redder than usual. In six hours, the coverings of the ovarian vesicles, or vesicles of De Graaf, seemed reddish. At the expiration of a day from conception, three vesicles in one of the ovaries, and five in the other, appeared changed, having become opaque and reddish. After twenty-seven, forty, and fifty hours, the cornua of the uterus and the tubes were very red, and one of the tubes had laid hold of the ovary; a vesicle was in the tube, and two in the right cornu of the uterus. These vesicles were as large as mustard seed. They were formed of two membranes, and were filled by a limpid fluid. On the fourth day, the ovary contained only a species of envelope, called, by De Graaf, a *follicle:* this appeared to be the capsule, which had contained the ovum. The ovum itself was in the cavity of the uterus, had augmented in size, and its two envelopes were very distinct. Here it remained loose until the seventh day, when it formed an adhesion to the uterus. On the ninth day, De Graaf observed a small opaque point, a kind of cloud, in the transparent fluid that filled the ovum. On the tenth day, this point had the shape of a small worm. On the eleventh, the embryo was clearly perceptible; and, from this period, it underwent its full developement, until the thirty-first day, when delivery took place.

Malpighi and Vallisnieri also observed, in their experiments, that after a fecundating copulation, a body was developed at the surface of the ovary, which subsequently burst, and suffered a smaller body to escape. This was laid hold of by the tube, and conveyed by it to the uterus. It is not, however, universally admitted, that this body is the impregnated ovum; some affirming, that it is a sperm similar to that of the male; and others, that it is an amorphous substance, which, after successive developements, becomes the new individual.

Haller exposed the females of sheep and of other animals to the males, on the same day; and killed them at different periods after copulation, for the purpose of detecting the whole series of changes, by which the vesicle is detached from the ovary and conveyed to the uterus.

Half an hour after copulation, one of the vesicles of the ovary appeared to be prominent; to have on its convexity a red, bloody spot, and to be about to break; in an hour or more, the vesicle gave way, and its interior seemed bleeding and inflamed. What remained of the vesicle in the ovary, and appeared to be its envelope, gradually became inspissated, and converted into a body of a yellowish colour, to which Haller gave the name *corpus luteum*. The cleft, by which the vesicle escaped, was observable for some time, but, about the eighth day, it disappeared. On the twelfth day, the corpus luteum became pale and began to diminish in size. This it continued to do until the end of gestation; and ultimately became a small, hard, yellowish or blackish substance, which could always be distinguished in the ovarium, by the cicatrix left by it. Its size was greater, the nearer the examination was made to the period of conception. In a bitch, for example, on the tenth day, it was half the size of the ovary; yet it proceeded, in that case, from one vesicle only. In multiparous animals, as many *corpora lutea* existed as fœtuses.

The experiments of Haller have been frequently repeated and with similar results. Magendie, whose trials were made on bitches, observed, that the largest vesicles of the ovary were greatly augmented in size, thirty hours after copulation; and that the tissue of the ovary, surrounding them, had acquired greater consistence, had changed colour, and become of a yellowish-gray. This part was the *corpus luteum*. It increased for the next three or four days as well as the vesicles; and seemed to contain, in its areolæ, a white, opaque fluid, similar to milk. The vesicles now successively ruptured the external coat of the ovary, and passed to the surface of the organ, still adhering to it, however, by one side. Their size was sometimes that of a common hazlenut, but no germ was perceptible in them. The surface was smooth, and the interior filled with fluid. Whilst they were passing to the uterus, the corpus luteum remained in the ovary, and underwent the changes referred to by Haller.

In similar experiments, instituted by MM. Prévost and Dumas, no change was perceptible in the ovary during the first day after fecun-

dation; but, on the second day, several vesicles enlarged, and continued to do so for the next four or five days, so that, from being two or three millimètres in diameter, they attained a diameter of eight. From the sixth to the eighth day, the vesicles burst, and allowed an ovule to emerge, which often escaped observation, owing to its not being more than half a millimètre in diameter, but was clearly seen by MM. Prévost and Dumas by the aid of the microscope. This part they term *ovule*, in contradistinction to that developed in the ovary, which they call *vesicle*. The latter has the appearance, at its surface, of a bloody cleft, into which a probe may be passed; and in this way it can be shown, that the vesicle has an interior cavity, which is the void space left by the ovule after its escape from the ovarium into the Fallopian tube. On the eighth day, in the bitch, the ovule passes into the uterus. All the ovules do not, however, enter that cavity at the same time;—an interval of three or four days sometimes occurring between them. When they attain the uterus, they are at first free and floating; and, if examined with a microscope magnifying twelve diameters, they seem to consist of a small vesicle, filled with an albuminous, transparent fluid. If examined in water, their upper surface has a mammiform appearance, with a white spot on the side. This is the cicatricula. These ovules speedily augment in size, and, on the twelfth day, fœtuses can be recognized in them.

From these facts, then, we may conclude, that the sperm excites the vesicles in the ovaria to developement; that the ova, within them, burst their covering, are laid hold of by the Fallopian tube, and conveyed to the uterus, where they remain during the period of gestation.

The exact time, required by the ovum or ova to make their way into the uterus, has not been accurately determined. Cruikshank found, that in rabbits forty-eight hours were necessary. Haighton divided one of the Fallopian tubes in a rabbit; and, having exposed the animal to the male, he observed that gestation occurred only on the sound side. On making this section after copulation, he found, that if it were executed within the two first days, the descent of the ovules was prevented; but if it were delayed for sixty hours, the ovules had passed through the tube and were in the cavity of the uterus. A case, too, is quoted by writers on this subject, on the authority of a surgeon named Bussières, who observed an ovoid sac, about the size of a hazelnut and containing an embryo, half in the Fallopian tube and half adherent to the ovary.

The minuteness of the calibre of the Fallopian tube is not as great a stumbling-block in the way of understanding how this passage is effected, as might appear at first sight. The duct is, doubtless, extremely small in the ordinary state; but it admits of considerable dilatation. Magendie asserts, that he once found it half an inch in diameter.

The period, that elapses between a fecundating copulation and the

passage of the ovum from the ovarium to the uterus, is different in different animals. In rabbits, it occurs on the third day after copulation; in bitches on the fifth, and in the human female, perhaps about the same time. Maygrier refers to a case of abortion twelve days after copulation; the abortment consisting of a vesicle, shaggy on its surface and filled by a transparent fluid.

One of the most instructive cases that we possess on this subject is given by Sir Everard Home. A servant maid, twenty-one years of age, had been courted by an officer, who had promised her marriage, in order that he might more easily accomplish his wishes. She was but little in the habit of leaving home, and had not done so for several days, when she requested a fellow servant to remain in the house, as she was desirous of calling upon a friend, and should be detained some time. This was on the seventh of January, 1817. After an absence of several hours, she returned with a pair of new corsets and other articles of dress, which she had purchased. In the evening she got one of the maid servants to assist her in trying on the corsets. In the act of lacing them, she complained of considerable general indisposition, which disappeared on taking a little brandy. Next day she was much indisposed. This was attributed to the catamenia not having made their appearance, although the period had arrived. On the following day, there was a wildness in her manner, and she appeared to suffer great mental distress. Fever supervened, which confined her to bed. On the 13th, she had an epileptic fit, followed by delirium, which continued till the 15th, when she expired in the forenoon. On making inquiries of her follow servants, many circumstances were mentioned, which rendered it highly probable, that on the morning of the 7th, when she was immediately on the point of menstruating, her lover had succeeded in gratifying his desires; and that she had become pregnant on that day, so that, when she died, she was in the seventh or eighth day of impregnation. Dissection showed the uterus to be much larger than in the virgin state and considerably more vascular. On accurately observing the right ovarium, in company with Mr. Clift, Sir Everard noticed, upon the most prominent part of its outer surface, a small ragged orifice. This induced him to make a longitudinal incision in a line close to this orifice, when a canal was found, leading to a cavity filled with coagulated blood and surrounded by a narrow yellow margin, in the structure of which the lines had a zig-zag appearance. The cavity of the uterus was then opened, by making an incision through the coats from each angle; and from the point where these incisions met, a third incision was continued down through the os uteri to the vagina. The os uteri was found completely blocked up by a plug of mucus, so that nothing could have escaped by the vagina; the orifices, leading to the Fallopian tubes, were both open, and the inner surface of the cavity of the uterus was composed of a beautiful efflorescence of coagulable lymph resembling the most

delicate moss. By attentive examination, Sir Everard discovered a small, spherical, transparent body concealed in this efflorescence, which was the impregnated ovum. This was submitted to the microscopic investigations of Mr. Bauer, who made various drawings of it, and detected two projecting points, which were considered to mark out, even at this early period, and before the ovum was attached to the uterus, the seat of the brain and spinal marrow. This case shows, that an ovum had left the ovarium, and that it was in the interior of the uterus, prior to the seventh or eighth day after impregnation.

But, it has been asked, is it a mere matter of chance, which of the ovarian vesicles shall be fecundated; or are there not some one or more that are riper than the rest, and that receive, by preference, the vivifying influence of the sperm? MM. Prévost and Dumas have shown, that such is the case with oviparous animals. They found, in their experiments, that not only were the vesicles of the ovaries of frogs of different sizes, but that the largest were always first laid, whilst the smallest were not to be deposited until subsequent years. In all the animals, whose eggs were fecundated externally, they seemed evidently prepared or maturated. We have, too, the most indubitable evidence that birds—although unquestionable virgins—may lay infecund eggs. Analogy would lead us to believe, that something similar may happen to the viviparous animal, and direct observation has confirmed the position. Not longer ago than the year 1808, the existence of corpora lutea in the ovaria was held to be full proof of impregnation. In that year, Charles Angus, Esq. of Liverpool, England, was tried at the Lancaster Assizes, for the murder of Miss Burns, a resident of his house. The symptoms, previous to her decease, and the appearances observed on dissection, were such as to warrant the suspicion that she had been poisoned. The uterine organs were also found to be in such a state as to induce a belief, that she had been delivered, a short time before her death, of a fœtus, which had nearly arrived at maturity. It was not, however, until after the trial, that the ovaria were examined, in the presence of a number of physicians, and a *corpus luteum* was distinctly perceived in one of them. The uterus was taken to London and shown to several of the most eminent practitioners there, all of whom appear to have considered that the presence of a *corpus luteum* proved the fact of pregnancy beyond a doubt. Such, indeed, is the positive averment of Haller, an opinion which was embraced by Haighton, who maintained that they furnish "incontestable proof" of previous impregnation. It was this belief, coupled with the fact, that division of the Fallopian tubes, in his experiments, prevented impregnation, whilst corpora lutea were found, notwithstanding, in the ovary, which led him to the strange conclusion, that the semen penetrates no forther than the uterus, and acts upon the ovaria by sympathy.

Sir Everard Home has satisfactorily shown, that corpora lutea exist independently of impregnation. "Upon examining," says he, "the ovaria of several women, who had died virgins, and in whom the hymen was too perfect to admit of the possibility of impregnation, there were not only distinct corpora lutea, but also small cavities round the edge of the ovarium, evidently left by ova, that had passed out at some former period;" and he affirms, that whenever a female quadruped is in heat, one or more ova pass from the ovarium to the uterus, whether she receives the male or not.

This view of the subject appears to have been first propounded by Blumenbach, in the *Transactions of the Royal Society of Göttingen*, in which he remarks, that the state of the ovaria of females, who have died under strong sexual passion, has been found similar to that of rabbits during heat; and he affirms, that in the body of a young woman, eighteen years of age, who had been brought up in a convent, and had every appearance of being a virgin, Vallisnieri found five or six vesicles pushing forward in one ovarium, and the corresponding Fallopian tube redder and larger than usual, as he had frequently observed in animals during heat. Bonnet, he adds, gives the history of a young lady, who died vehemently in love with a man of low station, and whose ovaria were turgid with vesicles of great size.

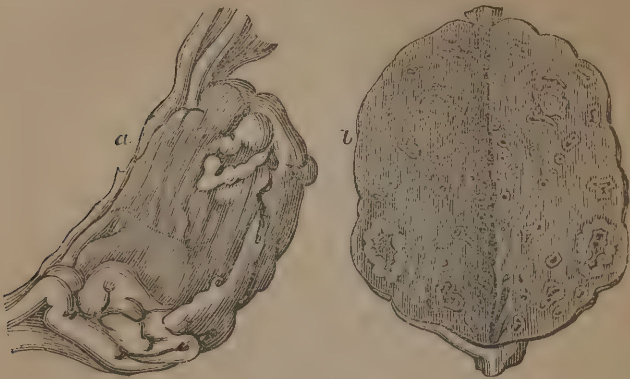
Buffon, again, maintained, that instead of the corpus luteum of Haller being the remains of the ovule, it is its rudiment; and that the corpus exists prior to fecundation, as he, also, found it in the virgin. Lastly, Dr. Blundell states, that he has in his possession a preparation, consisting of the ovaries of a young girl, who died of chorea under seventeen years of age, with the hymen, which nearly closed the entrance of the vagina, unbroken. In these ovaries, the corpora lutea are no fewer than four; two of them being a little obscure, but easily perceptible by an experienced eye. The remaining two are very distinct, and differ from the corpus luteum of genuine impregnation merely by their more diminutive size and the less extensive vascularity of the contiguous parts of the ovary. "In every other respect," says Dr. Blundell, "in colour and form, and the cavity which they contain, their appearance is perfectly natural, indeed, so much so, that I occasionally circulate them in the class-room, as accurate specimens of the luteum upon the small scale."

In a paper, published in the sixth volume of the *Transactions of the College of Physicians of London*, Mr. Stanley confirms the fact of the corpora lutea of virgins being of a smaller size than those that are the consequences of impregnation.

The structure of the corpus luteum is of a peculiar kind, and is not distinctly seen in small animals or in those that have numerous litters; but in the cow, which commonly has only one calf at a birth, it is so large, according to Sir Everard Home, that, when magnified, the structure can be made out. It is a mass of thin con-

volutions, bearing a greater resemblance to those of the brain than of any other organ. Its shape is irregularly oval, with a central cavity, and, in some animals, its substance is of a bright orange colour, when first exposed. The corpora lutea are found to make their appearance immediately after puberty, and they continue to succeed each other, as the ova are expelled, till the period arrives when impregnation can no longer be accomplished. Sir Everard's theory, regarding these bodies, is, that they are glands, formed purposely for the production of ova,—that they exist previous to, and

Fig. 155.



Corpora lutea.

are unconnected with, sexual intercourse,—and, when they have fulfilled their office of forming ova, they are removed by absorption whether the ova be fecundated or not.

Fig. 156.

Corpora lutea.

Figures, 155, *a* and *b*, afford an external and internal view of a human ovary, that did not contain the ovum, from which a child had been developed. It was taken immediately after the child was born. The corpus luteum is nearly of the full size. *a* and *b*, Fig. 156, afford an external and internal view of the ovarium, in which the impregnated ovum had been formed. The latter figure exhibits how much the corpus luteum had been broken down. In it we see a new corpus luteum forming.

From all these facts, then, we are perhaps justified in concluding with Sir Everard Home, and Messrs. Blundell, Saumarez, Cuvier, and the generality of physiologists, that the corpus luteum may be produced independently of sexual intercourse, by the mere excitement of high carnal desire, during which it is probable, that the digitated extremity of the Fallopian tube embraces the ovary, a vesicle bursts its covering, and a corpus luteum remains; the vesicle being conveyed along the tube into the uterus, but, being infecund, it undergoes no farther developement there; so that unimpregnated ova may, under such circumstances, be discharged, as we observe in the oviparous animal.

We have now endeavoured to demonstrate the part performed by the two sexes in fecundation. We have seen that the material furnished by the male is the sperm; that afforded by the female an ovum. The most difficult topic of inquiry yet remains,—how the new individual results from their commixture? Of the nature of this mysterious process we are, indeed, profoundly ignorant; and if we could make any comparison between the extent of our ignorance on the different vital phenomena, we should be disposed to decide, that the function of generation is, perhaps, the least intelligible. The new being must be stamped instantaneously as by the die. From the very moment of the admixture of the materials, at a fecundating copulation, the embryo must have within it the powers necessary for its own formation, and under impulses communicated by each parent,—as regards likeness, hereditary predisposition, &c. From this moment the father has no communication with it; yet we know, that it will resemble him in its features and in its predispositions to certain morbid states,—whilst the mother probably exerts but a slight and indirect control over it afterwards, her office being chiefly to furnish the homunculus with a nidus, in which it may work its own formation, and with the necessary pabulum. We have seen, that even so early as the seventh or eighth day after fecundation, two projecting points are observed in the ovum, which indicate the future situations of the brain and spinal marrow.

Our want of acquaintance with the precise character of this impenetrable mystery will not, however, excuse us from passing over some of the ingenious hypotheses, that have been entertained on the subject. These have varied according to the views that have

prevailed respecting the nature of the sperm; and to the opinions indulged regarding the matter furnished by the ovary. Drelincourt, who died in 1697, collected as many as two hundred and sixty hypotheses of generation; but they may all, perhaps, be classed under two,—the system of *epigenesis* and that of *evolution*.

1. *Epigenesis.*—According to this system, which is the most ancient of all, the new being is conceived to be built up of materials furnished by both sexes, the particles composing these materials having previously possessed the arrangement necessary for constituting it, or having suddenly received such arrangement. Still it is requisite that these particles should have some controlling agent to regulate their affinity, different from any of the ordinary forces of matter; and hence a force has been imagined to exist, which has been termed *cosmic*, *plastic*, *essential*, *nisus formativus*—the Bildungstrieb of the Germans—*force of formation*, &c.

Hippocrates maintained, that each of the two sexes possesses two kinds of seed, formed by the superfluous nutriment, and by fluids constituted of materials proceeding from all parts of the body, and especially from the most essential,—the nervous. Of these two seeds, the stronger begets males, the weaker females. In the act of generation, these seeds become mixed in the uterus, and by the influence of the heat of that organ, they form the new individual, by a kind of animal crystallization, male or female, according to the predominance of the stronger or the weaker seed.

Aristotle thought that it is not by seed that the female participates in generation, but by the menstrual blood. This blood he conceived to be the basis of the new individual, and the principles furnished by the male to communicate to it the vital movement, and to fashion it.

Empedocles, Epicurus, and various other ancient physiologists, contended, that the male and female respectively contribute a seminal fluid, which equally co-operate in the generation and developement of the fœtus, and that it belongs to the male or female sex, or resembles more closely the father or the mother, according as the orgasm of the one or the other predominates, or is accompanied by a more copious discharge:—

> "Semper enim partus duplici de semine constat;
> Atque utrique simile est magis id quodcumque creatur."
>
> Lucret. lib. iv.

Lactantius, in quoting the views of Aristotle on generation, fancifully affirms, that the right side of the uterus is the proper chamber of the male fœtus, and the left of the female,—a belief, which appears to be still prevalent amongst the vulgar, in many parts of Great Britain. But, he adds, if the male or stronger semen should, by mistake, enter the left side of the uterus, a male child may still be conceived; yet as it occupies the female department, its voice, face,

&c. will be effeminate. On the contrary, if the weaker or female seed should flow into the right side of the uterus, and a female fœtus be engendered, it will exhibit evidences of a masculine character.

The idea of Aristotle, with regard to the menstrual blood, has met with few partisans, and is undeserving of notice. That of Hippocrates, notwithstanding the objections which we now know to apply to it,—that the female furnishes no sperm, and that the ovaria are probably in no respects analagous to the testes of the male,—has had numerous supporters amongst the moderns, being modified to suit the scientific ideas of the time, and of the individual. Descartes, for example, considered the new being to arise from a kind of fermentation of the seed furnished by both sexes. Pascal, that the sperm of the male is acid, and that of the female alkaline; and that they combine to form the embryo. Maupertuis maintained, that, in each seed, parts exist, adapted for the formation of every organ of the body, and that, at the time of the union of the seed in a fecundating copulation, each of the parts is properly attracted and aggregated by a kind of crystallization.

The celebrated hypothesis of the eloquent but too enthusiastic Buffon is but a modification of the Hippocratic doctrine of epigenesis. According to him, there exist in nature two kinds of matter,—the living and the dead; the former perpetually changing during life, and consisting of an infinite number of small, incorruptible particles, or primordial monads, which he called *organic molecules.* These molecules, by combining in greater or less quantity with dead matter, form all organized bodies; and, without undergoing destruction, are incessantly passing from vegetables to animals, in the nutrition of the latter, and are returned from the animal to the vegetable by the death and putrefaction of the former. These organic molecules, during the period of growth, are appropriated to the developement of the individual; but, as soon as he has acquired his full size, the superfluous molecules are sent into depot in the genital organs, each molecule being invested with the shape of the part sending it. In this way he conceived the seed of both sexes to be formed of molecules obtained from every part of the system.

In the commixture of the seeds, during a fecundating copulation, the same force that assimilates the organic molecules to the parts of the body for their nourishment and increase, causes them, in this hypothesis, to congregate for the formation of the new individual; and, according as the molecules of the male or female predominate, so is the embryo male or female. The ingenuity of this doctrine was most captivating; and it appeared so well adapted for the explanation of many of the phenomena of generation, that it had numerous and respectable votaries. It accounted for the circumstance of procreation being impracticable, until the system had undergone its great developement at puberty. It explained why excessive indulgence in venery occasions emaciation and exhaustion; and why, on the other hand, the castrated animal is disposed to obesity,—the

depot having been removed by the mutilation. The resemblance of the child to one parent rather than to the other was supposed to be owing to the one furnishing a greater proportion of organic molecules than the other; and as more males than females are born, the circumstance was ascribed to the male being usually stronger, and therefore furnishing a stronger seed, or more of it.

Prior to this hypothesis, Leeuenhoek had discovered what he considered to be spermatic animalcules in the semen; but Buffon contested their animalcular nature, and regarded them as his vital particles or organic molecules; whilst he looked upon the ovarian vesicle as the capsule that contained the sperm of the female. The opinions of Buffon were slightly modified by Professor Blumenbach of Göttingen, and by Dr. Darwin. The former, like Buffon, divided matter into two kinds, possessing properties essentially different from each other;—the inorganic, and the organized; the latter possessing a peculiar creative or formative effort, which he called Bildungstrieb or *nisus formativus*,—a principle in many respects resembling gravitation, and endowing every organ, as soon as it acquires structure, with a *vita propria*. This force he conceived to preside over the arrangement of the materials, furnished by the two sexes in generation.

Darwin preferred to the term organic molecules that of *vital germs*, which he says are of two kinds, according as they are secreted or provided by male or female organs, whether animal or vegetable. In the subdivision, however, of the germs the term *molecule* is retained; but it is limited to those of the female; the vital germs or particles, secreted by the female organs of a bud or flower, or the female particles of the animal, being denominated by him *molecules* with formative propensities; whilst those secreted from the male organs are termed *fibrils* with formative appetencies. To the fibrils he assigns a higher degree of organization than to the molecules. Both, however, he asserts, have a propensity or appetency to form or create, and "they reciprocally stimulate and embrace each other and instantly coalesce; and may thus popularly be compared to the double affinities of chymistry."

Subtile as these hypotheses are, they are open to forcible objections of which a few only will suffice. The notion of this occult force is identical with that, which, we shall see hereafter, has prevailed as regards life in general, and it leaves the subject in the same obscurity as ever. What do the terms *plastic*, *cosmic*, or *vegetative force*, or Bildungstrieb express, which is not equally conveyed by *vital force*,—that mysterious property, on which so many unfathomable processes of the animal body are dependent—and of the nature or essence of which we know absolutely nothing? The objection, urged against the doctrine of Hippocrates,—that we have no evidence of the existence of female sperm—applies equally to the hypotheses that have been founded upon it; and even were we to grant, that the ovarium is a receptacle for female

sperm, the idea, that such sperm is constituted of organic molecules, derived from every part of the body, is entirely gratuitous. We have no facts to demonstrate the affirmative; whilst there are many circumstances, that favour the negative. The individual, for example, who has lost some part of his person—nose, eye or ear, or has had a limb amputated, still begets perfect children; yet whence can the molecules, in such cases, have been obtained? It is true, that if the mutilation affect but one parent, the organic molecules of the lost part may still exist in the seed of the other; but we ought, at least, to expect the part to be less perfectly formed in the embryo, which it is not. Where two docked horses are made to engender, the result ought, *a fortiori*, to be imperfect, as the organic molecules of the tail could not be furnished by either parent, yet we find the colt, in such cases, perfect in this appendage. An elucidative case is also afforded by the fœtus. If we admit the possibility of organic molecules constituting those parts that exist in the parents, how can we account for the formation of such as are peculiar to fœtal existence. Whence are the organic molecules of the navel-string, or of the umbilical vein, or of the ductus venosus, or the ductus arteriosus, or the umbilical arteries obtained?

These and other objections have led to the abandonment of the theory of Buffon, which remains merely as a monument of the author's ingenuity and elevation of fancy.

2. *Evolution.* According to this theory, the new individual preexists in some shape in one of the sexes, but requires to be vivified by the other, in the act of generation; after which it commences the series of developements or *evolutions*, which lead to the formation of an independent being.

The great differences of sentiment, that have prevailed under this view, have been owing to the part, which each sex has been conceived to play in the function. Some have considered the germ to exist in the ovary, and to require the vivifying influence of the male sperm to cause its evolution. Others have conceived the male sperm to contain the rudiments of the new being, and the female to afford it merely a nidus, and pabulum during its developement. The former class of physiologists have been called *ovarists*;—the latter *spermatists*, *seminists*, and *animalculists*.

The ovarists maintain, that the part furnished by the female is an ovum from the ovary; and this ovum they conceive formed of an embryo and of particular organs for the nutrition and first developement of the embryo; and adapted for becoming, after a series of changes or evolutions, a being similar to the one whence it has emanated. The hypothesis was suggested by the fact, that in many animals but a single individual is necessary for reproduction; and it is easier, perhaps, to consider this individual female than male; as well as by what is noticed in many oviparous animals. In these, the part, furnished by the female, is manifestly an ovum or

egg; and in many, such egg is laid before the union of the sexes, and is fecundated, as we have seen, externally. By analogy, the inference was drawn, that this may happen to the viviparous animal also.

The notion is said, but erroneously, to have been first of all advanced by Joseph de Aromatariis, in his *Epistola de generatione plantarum ex seminibus*, published at Venice, in 1625. It was developed by Harvey, who strenuously maintained the doctrine *omne vivum ex ovo.* The anatomical examinations of Sylvius, Vesalius, Fallopius, De Graaf, Malpighi, Vallisnieri and others,—by showing, that what had been previously regarded as female testes, and had been so called, were organs containing minute vesicles or ova, and hence termed, by Steno, *ovaria*,—were strong confirmations of this view, and startling objections to the ancient theory of epigenesis, and the problem appeared to be demonstrated, when it was discovered, that the vesicle or ovum leaves the ovarium, and passes through the Fallopian tube to the uterus.

The chief arguments, that have been adduced in favour of this doctrine are:—*First.* The difficulty of conceiving the formation, *ab origine*, of an organized body, as no one part can exist without the simultaneous existence of others. *Secondly.* The existence of the germ prior to fecundation in many living beings. In plants, for example, the grain exists in a rudimental state in the flower, before the pollen, which has to fecundate it, has attained maturity. In birds, too, the egg must pre-exist, as we find that those, which have never had intercourse with the male, can yet lay. This is more strikingly manifest in many fishes, and in the *batracia* or frog kind; where the egg is not fecundated until after extrusion. Spallanzani, moreover, asserts, that he could distinguish the presence of the tadpole in the unfecundated ova of the frog; and Haller, that of the chick in the infecund egg; at least he has seen them containing the yolk, which, in his view, is but a dependence of the intestine of the fœtus, and if the yolk exists, the chick exists also. *Thirdly.* The fact, before referred to, that in certain animals, a single copulation is capable of fecundating several successive generations. In these cases, it is argued, the germs of the different generations must have existed in the first. *Fourthly.* The fact of natural and accidental encasings or *emboîtements;* as in the bulb of the hyacinth, in which the rudiments of the flower are distinguishable; in the buds of trees, in which the branches, leaves, and flowers, have been detected in miniature, and greatly convoluted; in the jaws of certain animals, in which the germs of different series of teeth can be detected; in the volvox, a transparent animal, which exhibits several young ones encased in each other; in the common egg, which occasionally has another within it; and in the instances on record, in which human fœtuses have been found in the bodies of youths, of which there is a striking example in the Museum of the Royal College of Surgeons of London: and a simi-

lar case in a boy, fourteen years of age, has been related by Dupuytren.* *Fifthly.* The fact of the various metamorphoses, that take place in certain animals. Of these we have the most familiar instances in the batracia, and in insects. The forms which they have successively to assume are evidently encased. In the chrysalis, the outlines of the form of the future butterfly are apparent; and in the larva we observe those of the chrysalis. The frog is also apparent under the skin of the tadpole. *Sixthly.* The fact of artificial fecundation, which has been regarded, by the ovarists, as one of the strongest proofs of their theory; the quantity of sperm employed, as in the experiments of Spallanzani, already detailed, being too small, in their opinion, to assist in the formation of the new individual, except as a vivifying material. *Lastly.* They invoke the circumstance of partial reproductions, of which all living bodies afford more or less manifest examples;—as the reproduction of the hair and nails in man; of the teeth in the rodentia;—of the tail in the lizard; of the claw in the lobster; of the head in the snail, &c. &c. All these phenomena are, according to them, owing to each part possessing, within itself, germs destined for its reproduction, and requiring only favourable circumstances for their developement. The partisans of the doctrine of epigenesis, however, consider these last facts as opposed to the views of the ovarists; and they maintain, that, in such cases, there is throughout a fresh formation.

The chief objections, that have been urged against the hypothesis of the ovarists, are:—*First.* The resemblance of the child to the father—a subject which we shall refer to presently. The ovarists cannot of course deny that such resemblance exists; and they ascribe it to the modifying influence exerted by the male sperm, but without being able to explain the nature of such influence. They affirm, however, that the likeness of the mother is more frequent and evident. Certain cases of resemblance are weighty stumbling-blocks to ovism, or to the doctrine of a pre-existent germ in the female. It is a well-known fact, that six-fingered men will beget six-fingered children. How can we explain this upon the

* These are not the only cases, in which a fœtus has been found in the abdomen of a boy; and, perhaps, the explanation of Dr. Blundell is as philosophical as any that could be devised. A seed or egg, he remarks, though fecundated, may lie for years without being evolved. A serpent may become inclosed under the egg-shell of the goose; the shell probably forming over it as the animal lies in the oviduct of the bird. These facts Dr. Blundell applies to the phenomenon in question. When the boy was begotten, a twin was begotten at the same time,—but, while the former underwent his developement in the usual manner, the impregnated ovum of his companion lay dormant, and, unresistingly, became closed up, within the fraternal abdomen, as the viper in the egg-shell. For a few years, these living rudiments lay quiet within the body of the boy, and ultimately became developed so as to occasion the death of both. "The boy became pregnant with his twin brother, his abdomen formed the receptacle, where, as in the nest of a bird, the formation was accomplished." Cases of this kind of arrest of developement occasionally occur, where two or more ova are fecundated at the same time, or in succession. To this we shall refer under *Superfœtation.*

principle of the pre-existence of the germ in the female, and of the part played by the male sperm being simply that of a vivificative agent; and must we suppose, in the case of monstrosities, that such germs have been originally monstrous? *Secondly.* The production of *hybrids* is one of the strongest counter-arguments. They are produced by the union of the males and females of different species. Of these, the mule is the most familiar instance—the product of the ass and the mare. This strikingly participates of the qualities of both parents, and, consequently, the pre-existing germ in the female must have been more than vivified by the sexual intercourse. Its structure must have been altogether changed, and all the germs of its future offspring annihilated, as the mule is seldom fertile.

If a white woman marries a negro, the child is a mulatto; and if the successive generations of this woman are continually united to negroes, the progeny will ultimately become entirely black; or, at least, the white admixture will escape recognition. As a general rule, the offspring of different races have an intermediate tint between those of the parents; and the proportions of white and black blood, in different admixtures, have even been subjected to calculation, in those countries where negroes are common. The following table represents these proportions, according to the principles sanctioned by custom.

Parents.	Offspring.	Degree of Mixture.
Negro and white,	mulatto,	$\frac{1}{2}$ white, $\frac{1}{2}$ black.
White and mulatto,	terceron,	$\frac{3}{4}$ — $\frac{1}{4}$ —
Negro and mulatto,	griffo, or zambo, or black terceron,	$\frac{1}{4}$ — $\frac{3}{4}$ —
White and terceron,	quarteron,	$\frac{7}{8}$ — $\frac{1}{8}$ —
Negro and terceron,	black quarteron,	$\frac{1}{8}$ — $\frac{7}{8}$ —
White and quarteron,	quinteron,	$\frac{15}{16}$ — $\frac{1}{16}$ —
Negro and quarteron,	black quinteron,	$\frac{1}{16}$ — $\frac{15}{16}$ —

The two last are considered to be respectively white and black; and of these the former are white by law, and consequently free, in the British West India Islands. All these cases exhibit the influence exerted by the father upon the character of the offspring, and are great difficulties in the way of supposing that the male sperm is simply a vivifier of the germ pre-existing in the female. *Thirdly.* The doctrine of the ovarists does not account for the greater degree of fertility of cultivated plants and of domesticated animals. *Fourthly.* The changes, induced by the succession of ages on the animal and vegetable species inhabiting the surface of the globe, have been adduced against this hypothesis.

In examining the geological character of the various strata that compose the earth, it has been observed by geologists, that many of these contain imbedded the fossil remains of animals and vegetables. Now, those rocks on which others rest are the oldest, and the succes-

sive strata above these are more and more modern, and it has been found, that the organic fossil remains in the different strata differ more and more from the present inhabitants of the surface of the globe in proportion to the depth we descend; and that the remains of those beings, that have always been the companions of man, are found only in the most recent of the alluvial deposits,—in the upper crust of the earth.

In the older rocks the impressions are chiefly of the less perfect plants—as the ferns and reeds; and of the lower animals—the remains of shells and corals; whilst fish are uncommon. In the more recent strata, the remains of reptiles, birds and quadrupeds are apparent, but all of them differ essentially from the existing kinds, and in none of the formations of more ancient date has the fossil human skeleton been met with. The pretended human bones, conveyed by Spallanzani from the Island of Cerigo—the ancient Cythera—are not those of the human species any more than the bones of the *Homo diluvii testis* of Scheuchzer; and the skeleton of the savage Galibi, conveyed from Gaudaloupe and deposited in the British museum, is imbedded in a calcareous earth of modern formation. From these facts it has been concluded, that man is of a date posterior to animals, in all countries where fossil bones have been discovered.

These singular facts, furnished by modern geological inquiry, have been attempted to be explained by the supposition, that the present races of animals are the descendants of those, whose remains are met with in the rocks, and that their difference of character may have arisen from some change in the physical constitution of the atmosphere, or of the surface of the earth, producing a corresponding change in the forms of organized beings. It has been properly remarked, however, by Dr. Fleming, that the effect of circumstances on the appearance of living beings is circumscribed within certain limits, so that no transmutation of species was ever ascertained to have taken place, whilst the fossil species differ as much from the recent kinds, as the last do from each other; and he adds, that it remains for the abettors of the opinion to connect the extinct with the living races by ascertaining the intermediate links or transitions. This will probably ever be impracticable. The difference, indeed, between the extinct and the living races is in several cases so extreme, that many naturalists have preferred believing in the occasional formation of new organized beings. Linnæus was bold enough to affirm, that, in his time, more species of vegetables were in existence than in antiquity, and hence, that new vegetable species must necessarily have been ushered into being; and Wildenow embraced the views of Linnæus. Lamarck, one of the most distinguished naturalists of the day, openly professes his belief, that both animals and vegetables are incessantly changing under the influence of climate, food, domestication, the crossing of breeds, &c., and he remarks, that if the species, now in existence, appear to us fixed in their characters, it is because the circumstances, that modify those

species, require an enormous time for action; and would consequently require numerous generations to establish the fact.

The manifest effect of climate, food, &c. on vegetables and animals, he thinks, precludes the possibility of denying those changes on theoretical considerations; and what we call *lost species* are, in his view, only the actual species before they experienced modification.

It is proper, however, to observe, that the representations on the wall of one of the sepulchres in the valley of Beban el Molook, at Thebes, which are regarded by Champollion as having been executed upwards of two thousand years before the Christian era, enable the features of the Jew and of the negro, amongst others, to be recognized as easily as the representations of their descendants of the present day; so that, for the space of at least three thousand eight hundred years, no modification of the kind referred to by Lamarck seems to have occurred in the human species.

Another explanation has been afforded for these geological facts, and for the rotation, which we observe in the vegetable occupants of particular soils in successive years. It has been supposed, that as the seeds of plants and the ova of certain animals are so excessively minute as to penetrate wherever water or air can enter; and as they are capable of retaining the vital principle for an indefinite length of time, of which we have many proofs, and of undergoing evolution whenever circumstances are favourable, the crust of the earth may be regarded as a receptacle of germs, each of which is ready to expand into vegetable or animal forms, on the occurrence of conditions necessary for their developement. This is the hypothesis of *panspermia* or *dissemination of germs*, according to which the germs of the ferns and reeds were first expanded, and afterwards those of the staminiferous or more perfect vegetables; and, in the animal kingdom, first the zoophyte, and gradually the being more elevated in the scale; the organized bodies of the first period flourishing, so long as the circumstances, favourable to their developement, continued, and then making way for the evolution of their successors,—the changes effected in the soil by the growth and decay of the former probably favouring the evolution of the latter; which, again, retained possession of the soil so long as circumstances were propitious.

The changes that take place in forest vegetation are favourable to this doctrine. If, in Virginia, the forest trees be removed so as to make way for other growth, and the ground be prepared for the first cultivation, the *Phytolacca decandra* or *poke*, which was not previously perceptible on the land, usurps the whole surface. When Mr. Madison went with Gen. Lafayette to the Indian treaty, they discovered, that wherever trees had been blown down by a hurricane, in the spring, the white clover had sprung up in abundance, although the spot was many miles distant from any cleared land; and it has often been remarked, that where, during a drought in the spring, the

woods have taken fire and the surface of the ground has been torrefied, the water weed has made its appearance in immense quantities, and occupied the burnt surface.

The late Judge Peters, having occasion to cut ditches on his land, in the western part of Pennsylvania, was surprised to find every subterraneous tree that was met with, different from those at the time occupying the surface; and Mr. Madison informs us, that, in the space of sixty or seventy years, he has noticed the following spontaneous rotation of vegetables:—1. Mayweed; 2. Blue centaury; 3. Bottle-brush-grass; 4. Broomstraw; 5. White clover; 6. Wild carrot; and the last is now giving way to the blue grass.

The doctrine of panspermia is, however, totally inapplicable to the viviparous animal, in which the ovum is hatched within the body, and which, consequently, continues to live after the birth of its progeny; whilst the facts, furnished us by geology, seem clearly to show, that the developement of the animal kingdom has been successive, not simultaneous; but, under what circumstances the different animals were successively ushered into being, we know not.

Lastly, as regards the ovarists themselves;—they differ in essential points: whilst some are favourable to the doctrine of the *dissemination of germs*, believing, as we have seen, that ova or germs are disseminated over all space, and that they only undergo developement under favourable circumstances, as when they meet with bodies capable of retaining them, and causing their growth, or which resemble themselves; others assert, that the germs are inclosed in each other, and that they are successively aroused from their torpor, and called into life, by the influence of the seminal fluid; so that not only did the ovary of the first female contain the ova of all the children she had, but one only of these ova contained the whole of the human race. This was the celebrated system of *emboîtement des germes*, or *encasing of germs*, of which Bonnet was the propounder, and Spallanzani the promulgator. Yet how monstrous for us to believe, that the first female had, within her, the germs of all mankind, born, and to be born; or to conceive, that a grain of Indian corn contains within it all the seed, that may hereafter result from its culture. Many of the ovarists, again, and they alone who have anything like probability in their favour, believe, that the female forms her own ova, as the male makes his own sperm, by a secretory action; and, so far as the female is concerned in the generative process, we shall find that this is the only philosophical view; but it is imperfect in not admitting of more than a vivifying action in the materials furnished by the male.

About the middle of the seventeenth century, Hamme, Leeuenhoek, and Hartsöker, discovered a prodigious number of small moving bodies in the sperm of animals, which they regarded as animalcules. This gave rise to a new system of generation, directly the reverse of that of Harvey,—that of generation *ab animalculo maris*. As, in the Harveian doctrine, the germ was conceived to be

furnished by the mother and the vivifying influence to be alone exerted by the male, so, in this doctrine, the entire formation was regarded as the work of the father, the mother affording nothing more than a nidus, and appropriate pabulum for the homunculus or rudimental fœtus. Such was the opinion of Mohrenheim, and the spermatic doctrine was soon embraced by Boerhaave, Keil, Cheyne, Christian Wolf, Lieutaud and others. The pre-existing germ was accordingly now referred exclusively to the male; and, by some, the doctrine of *emboîtement* or encasing was extended to it.

In support of this hypothesis, the spermatists urged,—that the animalcules they discovered, were peculiar to the semen, and that they exist in the sperm of all animals, capable of generation; that they differ in different species, but are always identical in the sperm of the same animal, and in that of individuals of the same species; that they are not perceptible in the sperm of any animal until the age at which generation is practicable, whilst they are wanting in infancy and decrepitude; that their number is so considerable, that a drop of the sperm of a cock, scarcely equal in size to a grain of sand, contains 50,000; and lastly, that their size being so minute, is no obstacle to the supposition, that generation is accomplished by them; the disproportion between the trees of our forest and the seed producing them being nearly if not entirely as great as that between the animalcule and the being it has to develope.*

The difficulty with the spermatists or animalculists was to determine the mode in which the homunculus attains the ovary, and effects the work of reproduction. Whilst some asserted it to be only requisite, that the sperm should attain the uterus, whither it attracted the ovum from the ovarium; others imagined that the animalcule travelled along the Fallopian tube to the ovary; entered one of the ovarian vesicles; shut itself up there for some time, and then returned into the cavity of the uterus, to undergo its first developement, through the medium of the nutritive substance contained in the vesicle; and a celebrated pupil of Leeuenhoek even affirmed, that he not only saw these animalcules under the shape of the tadpole, as they were generally described, but that he could trace one of them, bursting through the envelope that retained it, and exhibiting two arms, two legs, a human head and a heart!

Although this doctrine was extremely captivating, and, for a time, kept the minds of many eminent philosophers in a state of delusive enthusiasm; † it was, subsequently, strongly objected to by many; and the great fact on which it rested—the very existence of the spermatic animalcules—was, and is, strenuously contested.

* Leeuenhoek estimated those of the frog at about the 1-10,000th part of a human hair, and that the milt of a cod may contain 15,000,000,000,000,000 of them.

† Dr. Thomas Morgan, in a work, published in 1731, thus expresses himself regarding this doctrine:—"That all generation is from an animalculum pre-existing in semine maris, is so evident in fact, and so well confirmed by experience and observation, that I know of no learned men, who in the least doubt of it."

Linnæus discredited the observations of Leeuenhoek: Verheyen denied the existence of the animalcules, and undertook to demonstrate that the motion, supposed to be traced in them, was a mere microscopic delusion;—whilst Needham and Buffon regarded them as organic molecules.

Of late years, MM. Prévost and Dumas have directed their attention to the subject; and their investigations, as on every other topic of physiological inquiry, are worthy of the deepest regard. The results of their examinations have led them to confirm the existence of these animalcules, and likewise to consider them as the direct agents of fecundation. By means of the microscope they detected them in all the animals, whose sperm they examined, and these were numerous. Whether the fluid was observed after its excretion by a living animal, or after its death, in the vas deferens or in the testicle, the animalcules were detected in it with equal facility.

They consider these bodies to be characteristic of the sperm, as they found them only in that secretion; being wanting in every other humour of the body, even in those that are excreted with the sperm, as the fluids of the prostate, and of the glands of Cowper, and although similar in shape, and size, and in the character of their locomotion in the individuals of the same species, they are of various shapes and dimensions in different species. In passing through the series of genital organs these animalcules experience no change, being as perfect in the testicle as at the time of their excretion; and they controvert the remark of Leeuenhoek, that they are met with apparently of different ages.

The animalcules were manifestly endowed with spontaneous motion, which gradually ceased,—in the sperm obtained during life by ejaculation, in the course of two or three hours; in that taken from the vessels after death, in fifteen or twenty minutes, and in eighteen or twenty hours, when left in its own vessels after death. In farther proof of the position, that these animalcules are the fecundating agents, MM. Prévost and Dumas assert, that they are only met with whilst reproduction is practicable:—that, in the human species, they are not found in infancy or decrepitude; and, in the majority of birds, are apparent in the sperm, only at the periods fixed for their copulation; facts which, in their opinion, show, that they are not mere infusory animalcules.

MM. Prévost and Dumas moreover affirm, that they appeared to be connected with the physiological condition of the animal furnishing them; their motions being rapid or languishing, according as the animal was young or old, or in a state of health or disease. They state, also, that in their experiments on the ova of the mammiferous animal, they observed animalcules filling the cornua of the uterus, and remaining there alive and moving, until the ovule descended into that organ, when they gradually disappeared; and they argue in favour of the influence of these animalcules;—that the

positive contact of the sperm is necessary for fecundation, and that the aura seminis is totally insufficient;—that the sperm, in twenty-four hours, loses its fecundating property, and it requires about this time for the animalcules to gradually cease their movements and perish; and, lastly, that having destroyed the animalcules in the sperm, the fluid lost its fecundating property. One of these experiments consisted in killing all the animalcules in a spermatized fluid,—whose fecundating power had been previously tested,—by repeated discharges of a Leyden phial: another consisted in placing a spermatized fluid on a quintuple filter, and repeating this, until all the animalcules were retained on the filter; when it was found, that the fluid, which passed through, had no fecundating power, whilst the portion retained by the filter had the full faculty; a result that had been obtained by Spallanzani, who found, besides, that he was capable of affecting fecundation with water in which the papers, used as filters, had been washed.

Lastly, MM. Prévost and Dumas, and Rolando, conjecture that the spermatic animalcule forms the nervous system of the new being, and that the ovule furnishes only the cellular frame-work in which the organs are formed; but this is mere hypothesis. The essays of these ingenious experimenters would seem to prove the existence of peculiar animalcules in the sperm, and their apparent agency in the generative process; yet, as we have before seen, all this has been recently questioned by Raspail, who is disposed to regard the fancied animalcules as mere shreds of the tissues of the generative organs ejaculated with the sperm.

It is scarcely necessary to remark, that all the objections which were urged against the system of the ovarists, as regards the proof in favour of an active participation of both sexes in the work of reproduction, are equally applicable to the views of those animalculists, who refer generation exclusively to the spermatic animalcule.

Such are the chief theories that have been propounded on the subject of generation. It has been already observed, that the particular modifications are almost innumerable. They may all, however, be classed with more or less consanguinity under some of the doctrines enumerated. Facts and arguments are strongly against any view that refers the whole process of formation to either sex. There must be a union of materials furnished by both, otherwise it is impossible to explain the similarity in conformation to both parents, which is often so manifest. Accordingly, this modified view of epigenesis is now adopted by most physiologists:—that at a fecundating copulation, the secretion of the male is united to a material, furnished by the ovarium of the female; that from the union of these elements the embryo results, impressed, from the very instant of such union, with life, and with an impulse to a greater or less resemblance to this or that parent, as the case may be; and that

the material, furnished by the female, is as much a secretion resulting from the peculiar organization of the ovarium, as the sperm is from that of the testicle,—life being capable, in this manner, of communication from father to child, without a necessity for invoking the incomprehensible and revolting doctrine of the pre-existence of germs.

This admixture of the materials, furnished by both sexes, accounts for the likeness that the child may bear to either parent, whatever may be the difficulty in understanding the precise mode in which they act in the formation of the fœtus. It has been attempted, however, by some, to maintain, that the influence of the maternal imagination during a fecundating copulation may be sufficient to impress the germ, within her, with the necessary impulse; and the plea has been occasionally urged in courts of justice. Of this we have an example in a well-known case, tried in New York, five-and-twenty years ago. A mulatto woman was delivered of a female bastard child, which became chargeable to the authorities of the city. When interrogated, she stated that a black man of the name of Whistelo was the father, who was accordingly apprehended, for the purpose of assessing him with the expenses. Several physicians, who were summoned before the magistrates, gave it as their opinion that it was not his child, but the offspring of a white man. Dr. S. Mitchell, however, who, according to Dr. Beck, seemed to be a believer in the influence of the imagination over the fœtus, thought it probable that the negro was the father. Owing to this difference of sentiment, the case was carried before the mayor, recorder, and several aldermen. It appeared in evidence, that the colour of the child was somewhat dark, but lighter than the generality of mulattos, and that its hair was straight, and had none of the peculiarities of the negro race.

The court very properly decided in favour of Whistelo, and of course against the testimony of Dr. Mitchell, who, moreover, maintained, that as alteration of complexion has occasionally been noticed in the human subject,—as of negroes turning partially white,—and in animals, so this might be a parallel instance. The opinion does not seem entitled to much greater estimation than that of the poor Irish woman, in a London police report, who ascribed the fact of her having brought forth a thick-lipped, woolly-headed urchin to her having eaten some black potatoes, during her pregnancy!

It is obvious, that the effect of the maternal imagination can only be invoked—by those who believe in its agency on the future appearance of the fœtus—in the case of those animals in which copulation is a part of the process. Where the eggs are first extruded and then fecundated, all such influence must be out of the question; and even in the viviparous animal we have seen, that experiments on artificial impregnation have shown, that not only has the bitch been fecundated by sperm injected into the vagina, but that the

resulting young have manifestly resembled the dog, whence the sperm had been obtained.

The strongest case in favour of the influence of the maternal imagination is given by Sir Everard Home. An English mare was covered by a quaga,—a species of wild ass from Africa, which is marked somewhat like the zebra. This happened in the year 1815, in the park of Earl Morton, in Scotland. The mare was only covered once; went eleven months, four days, and nineteen hours; and the produce was a hybrid, marked like the father. The hybrid remained with the dam for four months, when it was weaned and removed from her sight. She probably saw it again in the early part of 1816, but never afterwards. In February, 1817, she was covered by an Arabian horse, and had her first foal—a filly. In May, 1818, she was covered again by the same horse, and had a second. In June, 1819, she was covered again, but this year missed; but in May, 1821, she was covered a fourth time, and had a third; all being marked like the quaga.

Similar facts have been alluded to by other writers. Haller remarks, that the female organs of the mare seem to be corrupted by the unequal copulation with the ass, as the young foal of a horse from a mare, which previously had a mule by an ass, has something asinine in the form of its mouth and lips; and Becher says, that when a mare has had a mule by an ass, and afterwards a foal by a horse, there are evidently marks in the foal of the mother having retained some ideas of her former paramour,—the ass; whence such horses are commended on account of their tolerance and other similar qualities.

The mode in which the influence is exerted, in this and similar cases, is unfathomable; and the fact itself, although indisputable, is astounding. Sir Everard Home thinks that it is one of the strongest proofs of the effect of the mind of the mother upon her young that has ever been recorded. Although we are totally incapable of suggesting any satisfactory solution, it appears to us more probable, that the impression must have been made in these cases on the genital system, and probably upon the ovarian vesicles, rather than upon the mind of the animal.

Conception usually occurs without the slightest consciousness on the part of the female; and hence the difficulty of reckoning the precise period of gestation. Certain signs, as shivering, pain about the umbilicus, &c. are said to have occasionally denoted its occurrence, but these are rare exceptions, and the indications afforded by one are often extremely different from those presented by another. In those animals, in which generation is only accomplished during a period of generative excitement, the period of conception can be determined with accuracy; for, in by far the majority of such cases, a single copulation will fecundate; the existence of the state of *heat* indicating that the generative organs are ripe for conception. In the human female, where the sexual intercourse can take place at all

periods of the year, conception is by no means as likely to follow a single intercourse; for, although she may be always susceptible of fecundation, her genital organs are perhaps at no one time so powerfully excited as in the animal during the season of love. It is not for the physiologist to inquire into the morbid causes of sterility in either male or female; nor is it desirable to relate all the visionary notions which have prevailed regarding the circumstances that favour conception. It would certainly seem more likely to supervene when the venereal orgasm occurs simultaneously in both parties; and when the sperm is thrown well forwards towards the mouth of the uterus. We have already shown, that preternatural openings of the urethra, which interfere with this projection of the sperm in the proper direction, render fecundation less probable.

It has been generally affirmed by writers, that conception is apt to take place more readily immediately after menstruation; either, it has been imagined, because the uterus continues slightly open, so as to admit the sperm more easily into its cavity, or because the whole apparatus is in a state of some excitement. This opinion is problematical; and, accordingly, a female is in the habit of reckoning from a fortnight after her last menstrual period; for as she might have fallen with child immediately after menstruation, or not until immediately preceding the following menstruation; a difference of three weeks might occur; and she, therefore, takes the middle point between those periods; that is, ten days or a fortnight after her last menstruation, or, what is the same thing, ten days or a fortnight before the first obstructed menstruation. Sir Everard Home, however, differs on this topic from the generality of physiologists,—affirming that, in the human species, the fulness of the vessels of the womb, prior to menstruation, corresponds with the state of heat in the female quadruped, and shows that, at that period, the ova are most commonly fit for impregnation. "The females in India," he observes, "where, from the warmth of the climate, all the internal economy respecting the propagation of the species goes on more kindly than in changeable climates, reckon ten months as the period of utero-gestation. In the Apocrypha, the wisdom of Solomon, Chap. VII., v. 2,—'And in my mother's womb was fashioned to be flesh in the time of ten months.' This circumstance seems to prove, that immediately before menstruation, when all the appendages of the womb are loaded with blood, the ova and the ovaria are more frequently ready for impregnation, in the climates most congenial for propagation; and therefore the mode of reckoning is from the previous menstruation, which is ten months before the birth."

It has been attempted to ascertain what age and season are most prolific. From a register, kept by Dr. Bland, of London, it would appear, that more women, between the ages of twenty-six and thirty years, bear children than at any other period. Of two thousand one hundred and two women delivered, eighty-five were from fifteen to twenty years of age; five hundred and seventy-eight from twenty-

one to twenty-five; six hundred and ninety-nine from twenty-six to thirty; four hundred and seven from thirty-one to thirty-five; two hundred and ninety-one from thirty-six to forty; thirty-six from forty-one to forty-five; and six from forty-six to forty-nine.

At Marseilles, according to Raymond, women conceive most readily in autumn and chiefly in October; next in summer; and lastly in winter and spring; the month of March having fewest conceptions. Morand says, that July, May, June, and August, are the most frequent months for conception; and November, March, April, and October, successively, the least frequent. At the Havanna, according to tables, in the excellent "*Historia economico-politica y estadistica de la Isla de Cuba*," by the author's friend, Don Ramon de la Sagra, the monthly number of births, amongst the white population, during a period of five years,—from 1825 to 1829,—was in the following order:—October, September, November, December, August, July, June, April, May, January, March, and February. February, January, March and April are, therefore, the most frequent months for conception at the Havanna,—June, July, May and September the least so. Mr. Burns asserts, that the register for ten years of an extensive parish in Glasgow, renders it probable that August and September are most favourable for conception. M. Villermé, from an estimate founded on eight years' observations in France, comprising 7,651,437 births, makes the ratio of conceptions as follows:—May, June, April, July, February, March and December, January, August, November, September and October:—and lastly, Dr. Gouverneur Emerson, who has employed himself most profitably on the Medical Statistics of Philadelphia, has furnished a table of the number of births, during each month, for the ten years ending in 1830; according to which, the numbers are in the following order:—December, September, January, March, October, August, November, February, July, May, April and June,—the greatest number of conceptions occurring, consequently, in April, January, and May,—the least in October, August and September.

The human female is uniparous; one ovum only, as a general rule, being fecundated; numerous other animals are multiparous, or bring forth many at a birth. The law, however, on this subject is not fixed. Occasionally the human female will bring forth twins, triplets or quadruplets; whilst the multiparous animal is not always delivered of the same number. It is impossible to account for those differences. The ovarists refer them to the female; the animalculists to the male; and facts have been found to support both views. Certain females, who have been frequently married, have been multiparous with each husband; and analogous facts have occurred to males under similar circumstances. Ménage cites the case of a man, whose wife brought him twenty-one children in seven deliveries; and the same individual having impregnated his servant-maid, she brought forth triplets likewise. In 1755, it is asserted, that a peasant was presented to the Empress of Russia, who was

seventy years of age, and had been twice married. His first wife had fifty-seven children at twenty-one births. In four deliveries she had four children at each; in seven, three; and in six, two. This appears to be the *ne plus ultra* of such cases!

In the *Hospice de la Maternité*, of Paris, it has been observed, that twins occur once in about eighty cases. In the Westminster Hospital, the same ratio has been found to prevail. In the British Lying-in Hospital, the proportion was not greater than 1 in 91; whilst in the Dublin Lying-in Hospital the cases were nearly twice as frequent, or about 1 in 57. In this country, the average, according to Dr. Dewees, is about 1 in 75. Triplet cases were found to occur in the *Hospice de la Maternité*, of Paris, about once in 9000 times; and in the Dublin Hospital once in 5050 times; the balance being largely in favour of the prolific powers of the Irish. Dr. Dewees affirms, that, in more than 9000 cases, he has not met with an instance of triplets. Of 36,000 cases in the *Hospice de la Maternité* not one brought forth four children; yet there are cases on record where five have been born at a birth. Beyond this number the tales of authors ought perhaps to be esteemed fabulous.

In referring to the following table it will be found to prevail, as a general rule, amongst quadrupeds, that the largest and most formidable bring forth the fewest young; whilst the lower tribes are unusually fruitful; the number produced compensating, in some measure, for their natural feebleness, which renders them constantly liable to destruction. On the other hand, were the larger species to be as prolific as the smaller, the latter would soon be blotted from existence. What would have been the condition of animated nature, if the gigantic mastodon, once the inhabitant of our plains, could have engendered as frequently and as numerously as the rabbit.

For wise purposes, it has also been ordained, that the more formidable animals seldom begin the work of reproduction until they have nearly attained their full size; whilst those that bring forth many commence much earlier.

Lastly, there is some correspondence, likewise, between the duration of gestation and the size of the animal.

Animals.	Duration of gestation.	Number of young.	Animals.	Duration of gestation.	Number of young.
Ape, - -	about 9 months,	1	Lioness,	- -	4 or 5
Bat, - -	- -	2	Tigress,	- -	4 or 5
Rat, - -	5 or 6 weeks,	5 or 6	Cat, -	8 weeks,	4 or 5
Mouse, -	- -	6 to 10	Seal, -	- -	2
Hare, - -	30 days,	4 or 5			
Rabbit, -	Do.	Do.	Mare, -	11 months and some days,	1
Guinea-pig,	3 weeks,	5 to 12			
Squirrel, -	6 weeks,	4 or 5	Ewe, -	5 months,	1 or 2
Mole, -	- -	4 or 5	Goat, -	$4\frac{1}{2}$ months,	1, 2, or 3
Bear, - -	- -	2 or 3	Cow, -	9 months,	1 or 2
Otter, -	9 weeks,	4 or 5	Reindeer,	8 months,	2
Bitch, -	9 weeks,	4 to 10	Hind, -	Do.	1 or 2
Ferret, -	6 weeks,	6 or 7	Sow, -	4 months,	6 to 12 & more
Wolf, -	10 weeks,	5 to 9			
Opossum,	- -	4 or 5	Camel,	12 months,	1
Kangaroo,	- -	1	Walrus,	9 months,	1
Jackall, -	- -	6 to 8	Elephant,	2 years,	1
Fox, - -	10 weeks,	4 or 5	Whale,	9 or 10 mos.	1 or 2

Conception being entirely removed from all influence of volition, it is obviously impracticable, by any effort of the will, either to modify the sex of the fœtus, or its general physical and moral characters. Yet idle and absurd schemes have been devised for both one and the other.

The older philosophers, as Hippocrates and Aristotle, believed that the right testicle and ovary furnished the rudiments of males; and the same organs, on the left side, those of females: some of the older writers, *de Re rustica*, assert, that this was the result of their experiments with the ram. These statements gave rise to a pretended "art of procreating the sexes at pleasure," which has even been seriously revived in our own time. Mr. John Hunter published an experiment in the *Philosophical Transactions*, which was instituted for the purpose of determining, whether the number of young be equally divided between the ovaria. He took two sows from the same litter, deprived one of an ovarium, and counted the number of pigs each produced during its life. The sow with two ovaria had one hundred and sixty-two: the spayed sow only seventy-six. Hence he inferred, that each ovarium had nearly the same proportion. Yet, in this experiment, he makes no mention of the interesting fact regarding the proportion of the males in the two cases, and whether they were not all of the same sex in the sow that had been spayed. Had his attention been drawn to this point, the results would have been sufficient to arrest the strange hypothesis brought forward by Millot, who boldly affirmed, that males are produced by the right

ovarium, and females by the left; asserting, that he could so manage the position of the woman during copulation, that she should certainly have a boy or a girl, as might have been determined upon: and he published the names of mothers, who had followed his advice, and had succeeded in their wishes. A case, related by Dr. Granville, of London, to the Royal Society, has completely exhibited the absurdity of this doctrine. A woman, forty years of age, died at the *Hospice de la Maternité*, of Paris,—six or seven days after delivery,—of what had been supposed to be a disease of the heart. The body was opened in the presence of Dr. Granville, and the disease was found to be aneurism of the aorta. On examining the uterus, it was found to be at least four times the size of what it is during the unimpregnated state. It had acquired its full developement on the right side only, where it had the usual pyriform convexity; whilst the left formed a straight line, scarcely half an inch distant from the centre, although it was more than two inches from the same point to the outline of the right side. The Fallopian tube and the ovarium, with the other parts on the right side, had the natural appearance; but *they were not to be found on the left.* Yet this woman had been the mother of eleven children of both sexes; and a few days before her death had been delivered of twins;—one male and one female. M. Jadelot, too, has given the dissection of a female, who had been delivered of several children—boys and girls; yet she had no ovary or Fallopian tube on the right side. Lepelletier asserts that he saw a similar case in the Hospital at Mans, in 1825, and the *Recueils* of the *Sociéte de Medécine*, of Paris, contains the history of an extra-uterine gestation, in which a male fœtus was contained in the left ovary.

Independently of this decisive case, it has been found, that when one of the ovaries has been entirely disabled by disease, the other has conceived of both sexes. In rabbits, an ovary has been removed; yet both male and female fœtuses have subsequently been engendered; and if the gravid uterus of one of those animals be examined, male and female fœtuses will be found in the same cornu of the uterus, all of which, owing to the peculiar construction of the uterus in those animals,—the cornu forming the main part of the organ,—must manifestly have proceeded from the corresponding ovary. We are totally unaware, therefore, of the circumstances that give rise to the sex of the new being, although satisfied that it is in no respect influenced by the desires of the parents. We shall see, indeed, hereafter, that some distinguished physiologists believe, that the sex is not settled at the moment of conception, and that it is determined at a later period, after the embryo has undergone a certain developement.

It is an ancient opinion, which seems to be in some measure confirmed by what we notice in certain animals, that the character of the offspring is largely dependent upon the moral and physical qualities of the parent;—and a Dr. Robert, of Paris, in a dissertation under the pompous title of *Megalanthropogenesis*, has fancifully main-

tained, that the race of men of genius may be perpetuated by uniting them to women possessed of the same faculties. Similar views are maintained in the "Callipædia" of Claude Quillet.

It is an old opinion, that the procreative energy of the parents has much to do with the mental and corporeal activity of the offspring. Hence it is, that bastards have been presumed to excel in this respect. Such is the view of Burton in his "Anatomy of Melancholy," and the same idea is put, by Shakespeare, into the mouth of Edmund:

> "Why brand they us
> With base? with baseness? bastardy? base? base?
> Who in the lusty stealth of nature take
> More composition and fierce quality
> Than doth, within a dull, stale, tired bed
> Go to the creating a whole tribe of fops
> Got 'tween sleep and wake."
>
> *King Lear*, Act 1, Scene 2.

This, we have no doubt, is erroneous. A great deal depends upon the condition of the parents as regards their organization and strength of constitution. The remark—"fortes creantur fortibus et bonis"—is true within certain limits;—but we have no proof that the ardour of the procreative effort can have any such influence; and the ratio of instances of bastards, who have been signalized for the possession of unusual vigour—mental or corporeal—to the whole number of illegitimates, is not greater than in the case of those born in wedlock.

To elucidate the effect of the condition of the parent on the future progeny, M. Girou de Bussaringue mentions that a violent blow was given to a bitch, whilst lined, in consequence of which she was paraplegic for some days. She brought forth eight pups, all of which, except one, had the hind legs wanting, malformed, or weak.

Of late, also, it has been attempted to show, that the corporeal vigour of the parents has much to do even with the future sex. M. Girou de Bussaringue instituted a series of experiments on different animals, but especially on sheep, to discover, whether a greater number of male or female lambs may not be produced at the will of the agriculturist. The plan, adopted to insure this result, was to employ very young rams in that division of the flock whence it was desired to obtain females; and strong and vigorous rams, of four or five years of age, in that from which males were to be procured. The result would seem to show, that the younger rams begat females in greater proportion, and the older, males. M. Girou asserts, that females commonly predominate amongst animals, which live in a state of 'polygamy,' and it is asserted, that the same fact has been observed, in Turkey, and Persia, in our own species; but statistical facts are wanting on this subject.

It appears, that the proportion of males born to the females is every where pretty nearly the same. The calculations of Hufeland give the numbers in Germany as 21 to 20; and the census of Great

Britain, taken in 1821, estimates them as 21 to 20.066. In the Dublin Lying-in Hospital, during ten years, the ratio was as 21 to 19.33; and in the Eastern District of the Royal Maternity Charity of London, during the year 1830, it was as 21 to 19.64. In Philadelphia, according to the tables of Dr. Emerson, the proportion from 1821 to 1830, was as 21 to 19.43.

Although, however, a greater number of males may be born, they seem more exposed to natural or accidental death, for amongst adults the balance is much less in their favour, and indeed the number of adult females rather exceeds that of the males.

To conclude. It has been an oft agitated question, whether, after an ovule has been impregnated and passed down into the cavity of the uterus, another ovule may not be fecundated; so that the products of two conceptions may undergo their respective developements in the uterus, and be delivered at an interval corresponding to that between the conceptions. Many physiologists have believed this to be possible, and have given it the name of *superfœtation.* The case, cited from Sir Everard Home, of the young female, who died on the seventh or eighth day after conception, exhibits that the mouth of the womb is at a very early period completely obstructed by a plug of mucus; and that the inner surface of the uterus is lined by an efflorescence of coagulable lymph, the nature of which will be described under the next head.

When such a change has been effected, it would seem to be impossible for the male sperm to reach the ovary; and, accordingly, the general belief is, that superfœtation is only practicable prior to these changes,—which may perhaps require twenty-four hours for their accomplishment,—and where there is a second vesicle ripe for impregnation. Of this kind of superfœtation it is probable, that twin and triplet cases are often, if not always, examples; one ovule being impregnated at one copulation, and another at the next. It seems also to be common in animals. The dog-breeders have often remarked, that a bitch, after having been lined, will readily admit a dog of a very different kind to copulate with her; and where this has occurred, two different descriptions of puppies have been brought forth; some resembling each of the fathers. Sir Everard Home states, that a setter-bitch was lined in the morning by a pointer. The bitch went out with the game-keeper, who had with him a Russian setter of his own, which also lined her in the course of the afternoon. She had a litter of six pups; two only of which were preserved. One of these bore an exact resemblance to the pointer, the other to the Russian setter,—the male influence being predominant in each.

Of this kind of superfœtation or double conception we have several instances on record;—of which the following are amongst the most striking, the male parents of the respective fœtuses having differed in colour. The first is the well-known case, cited by Buf-

son, of a female at Charleston, South Carolina, who was delivered in 1714 of twins, within a very short time of each other. One of these was black, the other white. This circumstance led to an inquiry, when the woman confessed, that on a particular day, immediately after her husband had left his bed, a negro entered her room, and compelled her to gratify his wishes, under threats of murdering her. Several cases of women in the West India Islands having had, at one birth, a black and a white child, are recorded in the *Transactions of the Royal Society* of London; and Dr. Moseley, in his work "On Tropical Diseases," gives the following case, which is very analogous to that described by Buffon. A negro woman brought forth two children at a birth, both of a size, one of which was a negro, the other a mulatto. On being interrogated, she said, that a white man, belonging to the estate, came to her hut one morning before she was up, and that she received his embraces soon after her black husband had quitted her. Sir Everard Home likewise asserts, that a particular friend of his "knows a black woman, who has two children now alive, that are twins and were suckled together; one quite black, the other a mulatto. The woman herself does not hesitate in stating the circumstances: one morning just after her husband had left her, a soldier for whom she had a partiality came into the hut, and was connected with her, about three or four hours after leaving the embraces of her husband." One of the author's pupils, Mr. N. J. Huston, of Harrisonburg, Virginia, has also communicated to him the particulars of the case of a female who was delivered in March, 1827, of a negro child and a mulatto, on the same night. Where negro slavery exists, such cases are sufficiently numerous.

So far, therefore, as regards the possibility of a second vesicle being fecundated, prior to the closure of the os uteri by the tenacious mucus and the flocculent membranous secretion from the interior of the uterus, or by the decidua, no doubt, we think, can be entertained. But, except in cases of double uterus, it would seem to be impracticable afterwards; although cases have been adduced to show its possibility. Still these may perhaps be explained under the supposition, that the uterine changes, above referred to, may not be as rapidly accomplished in some cases as in others; and, again, the period of gestation is not so rigidly fixed, but that children, begotten within twenty-four hours, may still be born at a distance of some weeks from each other. A case happened to the author in which nearly three weeks elapsed between the birth of twins, in whose cases the ova were probably fecundated either at the same copulation or within a few hours of each other.

It may happen, too, that although two ova may be fecundated, both embryos may not undergo equal developement. One, indeed, may be arrested at an early stage, although still retaining the vital principle. In such a case, the other will generally be found larger than common. A case of this kind occurred recently in the prac-

tice of the Author's friend, Professor Hall, of the University of Maryland. On the 4th of October last, (1835) a lady was delivered of a female fœtus, 2 inches and 10 lines in length. This occurred about half-past eight, in the morning; and, at two o'clock on the following morning, she was delivered of a second child, which weighed $9\frac{1}{2}$ pounds. The fœtus, whose developement was arrested, was seen by the Author. When first extruded, it gave no evidences of decay, and in colour and general characters resembled the fœtus of an ordinary abortion.

When the fecundated ovum has been laid hold of by the fimbriated extremity of the Fallopian tube, and through this channel has reached the cavity of the uterus, it forms a union with this viscus, to obtain the nutritive fluids, that may be required for its developement, and to remain there during the whole period of *pregnancy* or *utero-gestation*;—a condition which will now require some consideration.

Immediately after a fecundating copulation, and whilst the chief changes are transpiring in the ovary, certain modifications occur in the uterus. According to some, it dilates for the reception of the ovum. Bertrandi found this to be the case in extra-uterine pregnancy, and in females whom he opened at periods so near to conception, that the ovum was still floating in the uterus. Its substance appeared at the same time redder, softer, less compact, and more vascular than usual. In the case to which we have more than once alluded from Sir Everard Home, the lining of the uterus was covered by a beautiful flocculent appearance, about the seventh or eighth day after impregnation. The soft flocculent membrane, which forms in this way, is the *membrana caduca*, or *decidua*, first described by Hunter;—the *epichorion* of Chaussier; the *tunica exterior ovi*, *caduca*, *crassa*, *membrana cribrosa*, *membrana ovi materna*, of others.

The arrangement of this membrane has given rise to some discussion. Wm. Hunter conceived it to be thicker the nearer to the time of conception, and that it became gradually thinner during pregnancy; still existing, however, during delivery, and being then thrown off,—whence its name *decidua*,—and renewed at each pregnancy. He considered it to have three apertures, one corresponding to the os uteri, and one to each Fallopian tube; that, at first, it consisted of one layer adherent to the uterus; but, subsequently, a second formed, which adhered to the ovum, and which he called *tunica decidua reflexa*.

The opinions of most of the anatomists of the present day are in favour of one of two views. It is maintained by some, that one of the first effects of conception is to cause the secretion of a considerable quantity of a sero-albuminous substance from the inner surface of the uterus; so that the organ becomes filled with it. At first, when the ovum arrives in the uterus, it falls into the midst of this

secretion, gradually absorbing a part by its outer surface for its nutrition. The remainder is organized into a double membrane, one corresponding to the uterus, the other adhering to the ovum. This sero-albuminous substance has been assimilated, both to the white, with which the eggs of birds become invested in passing through the oviduct, and to the viscid substance, that envelopes the membranous ova of certain reptiles. It is conceived to plug up both the orifices of the Fallopian tubes, and that of the uterus; and, according to Krummacher and Dutrochet, it has been seen extending into the tubes; whilst the remains of that, which plugged up the os uteri, has been recognized under the shape of a nipple on the top of the aborted ovum.

By others, it is held that the decidua is slightly organized even prior to the arrival of the ovum, lining the whole of the cavity and being devoid of apertures; so that when the ovum passes along the tube and attains the cornu of the uterus, it pushes the decidua before it; the part so pushed forwards constituting the *tunica decidua reflexa*, or *ovuline*, and enveloping the whole of the ovum except at the part where the decidua leaves the uterus to be reflected over it. This is the seat of the future *placenta.*

Such is the opinion of Velpeau. Impregnation, he says, occasions a specific excitation in the uterus, promptly followed by an exhalation of coagulable matter. This concretes, and is soon transformed into a kind of cyst or ampulla, filled with a transparent or slightly rose-coloured fluid. This species of bladder is in contact with the whole surface of the uterine cavity, and sometimes extends into the commencement of the tubes, and most frequently into the upper part of the cervix uteri, in the form of solid, concrete cords; but it is never, he says, perforated naturally, as Hunter, Bojanus, Lee and others have maintained. The decidua uteri, according to Velpeau, retains a pretty considerable thickness, especially around the placenta, until the end of gestation; the decidua reflexa, on the contrary, becomes insensibly thinner and thinner, so that, at the full period, it is, at times, of extreme tenuity. Towards the third or fourth month—a little sooner or later—they touch and press upon each other, and remain in a more or less perfect state of contiguity, until the expulsion of the secundines, but Velpeau asserts, they are never confounded. The decidua—the true as well as the reflected—is esteemed by him a simple concretion,—a layer without regular texture,—the product of an excretion from the lining membrane of the uterus; on this account, he terms it 'anhistous membrane' (from αν, privative, and ἱστος 'a web') or 'membrane without texture.' There has, indeed, been a striking dissatisfaction with the name 'decidua.' Besides the appellatives already given, Dutrochet has proposed to call it *épione*, Breschet, *périone*, and Burdach, *nidamentum.*

The use of the decidua is, in Velpeau's opinion, to retain the fecundated ovum to a given point of the uterine cavity; and if his

views of its arrangement were correct, the suggestions would be good. In favour of this arrangement, a good deal might be said. If there were apertures in the decidua, corresponding to the Fallopian tubes, it would seem, that the ovum ought more frequently to fall into the sero-albuminous matter about the cervix uteri, and attachment of the placenta over the os uteri ought, perhaps, to occur more frequently than it is known to do. Under M. Velpeau's doctrine, the attachment of the placenta ought rather to be near the cornu of the uterus, which is, in fact, the case. Of 34 females, who died in a state of pregnancy at the *Hôpital de Perfectionnement*, an examination of the parts exhibited, that, in twenty, the centre of the placenta corresponded to the orifice of the Fallopian tube: in three it was anterior to it: in two posterior! in three beneath: and in six near the fundus of the uterus. It is not so easy to subscribe to his assertions, regarding the 'anorganic' nature of the decidua. Many excellent observers have affirmed, not only that this membrane exists between the placenta and the uterus, which M. Velpeau's view, of course, renders impossible, but that numerous vessels pass between it, the uterus, and the placenta. We know, too, that the safest and most effectual mode of inducing premature labour is to detach the decidua from the cervix uteri, or, in other words, to break up the vessels that form the medium of communication between it and the lining membrane of the uterus. It may be said, indeed, that the mere separation of the 'anorganic pellicle'—as M. Velpeau designates it—is a source of irritation, and may excite the uterus to the expulsion of its contents, and this is possible; but he affirms, that no tissue attaches the decidua to the uterus; and that it adheres to the inner surface of the organ merely in the manner of an excreted membraniform shell (*plaque*.)

The views of Lepelletier and Raspail coincide with those of Velpeau as to the decidua being an excretion; but those of the latter are modified by his peculiar opinions. He maintains, that the surfaces of an organ—whether external or internal—having once fulfilled their appropriate functions, become detached and give place to the layer beneath them: and we have before remarked, that he considers the secretions of the mucous and serous membranes to be constituted of the *detritus* of those membranes. Now, that which happens to the intestinal canal and the bladder must likewise happen, he affirms, to the uterus, and as, at the period of gestation, it surpasses in developement, elaboration and vitality, every other living organ, it ought necessarily to cast off its layers, in proportion as they have executed the work of elaboration. These *deciduous* layers constitute the *decidua*, on which, he says, traces of a former adhesion to the parietes of the uterus, and of the three apertures into the organ, may be met with.

But the very existence of a decidua reflexa has been denied. It is so by Dr. Granville, who affirms, that it is now scarcely admitted by one in ten of the anatomists of the European continent. He

refers to a specimen of an impregnated uterus in the Museum of the Royal College of Surgeons of London, which exhibits distinctly a round ovum, naturally suspended within the decidua, as a globe may be supposed to hang from some point of the interior of an oblong sac; and to two specimens, in the collection of Sir Charles Clarke, exhibiting an ovulum, which has already penetrated about an inch into the cavity of the uterine decidua; but neither in these, nor in the specimen of the Royal College, is any part of the uterine decidua pushed forward. The ovum appears to have its natural covering; and, in the College specimen, there is a large space between them and the deciduous lining of the uterus. Dr. Granville regards the decidua reflexa to be the external membrane of the ovum, to which Professor Boër, of Königsberg, gave the name 'cortical membrane,' and which Dr. Granville terms *cortex ovi.* To this membrane—and to the decidua uteri, as connected with the placenta—we shall have to refer hereafter.

Such is the uncertain state of our information on this interesting topic of intra-uterine anatomy.

The decidua manifestly does not belong to the ovum; for it not only exists prior to the descent of the ovum into the uterus, but is even formed, according to Breschet, in all cases of extra-uterine pregnancies. Chaussier saw it in several cases of tubal gestation. It existed in a case of abdominal pregnancy, cited by Lallemant, and, according to Adelon, Evrat affirms, that one is secreted after every time of sexual intercourse,—which is apocryphal.

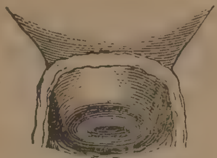
When the ovum attains the interior of the uterus, which it does in the first five or six days after conception, it forms, in a short space of time, a connexion with the uterus by means of the placenta, in the mode to be mentioned hereafter. During its developement, it is requisite that the uterus should be correspondently enlarged, in order to afford room for it, as well as to supply it with its proper nutriment. These changes in the uterine system will engage us exclusively at present.

During the first two months, the augmentation in size is not great, and chiefly occurs in the pelvis; but, in the fourth, the increase is more rapid. The uterus is too large to be contained in the pelvis, and consequently rises into the hypogastrium. During the next four months, it increases in every direction, occupying a larger and larger space in the cavity of the abdomen, and crowding the viscera into the flanks and the iliac regions. At the termination of the eighth month, it almost fills the hypogastric and umbilical regions; and its fundus approaches the epigastric region. After this, the fundus is depressed and approaches the umbilicus, leaving a flatness above, which has given rise to the old French proverb:—*En ventre plat enfant y a.*

During the first five months of utero-gestation, the womb experiences but little change, maintaining a conoidal shape. After this,

however, the neck diminishes in length, and is ultimately almost entirely effaced. The organ has now a decidedly ovoid shape, and its bulk is, according to Haller and Levret, eleven and a half times greater than in the unimpregnated state. Its length, at the full period, has been estimated at about a foot; its transverse diameters at nine inches; its circumference, on a level with the Fallopian tubes, at twenty-six inches; and, at the uterine portion of the cervix uteri, thirteen inches. Its weight, which, prior to impregnation, was from fourteen to eighteen drachms, is, at this time, from a pound and a half to two pounds.

Fig. 157.



Cervix uteri at three months.

Fig. 158.

Cervix uteri at six months.

Fig. 159.

Cervix uteri at nine months.

Whilst the uterus is undergoing expansion, the size and situation of the parts, attached to it, also experience modification. The broad ligaments are unfolded; the ovaries and Fallopian tubes are raised a little, but are subsequently applied against the sides of the uterus. The vagina is elongated. The round ligaments yield to the elevation of the organ as far as their length will permit; but, ultimately, they draw the uterus forwards, so that the great vessels of the abdomen are not injuriously compressed. The parietes of the abdomen are so much distended that the cuticle yields, so that an appearance of cicatrices always exists on the abdomen of one who has borne children; and, occasionally, the fasciculi of the abdominal muscles will separate so as to give rise to ventral hernia.

The changes, produced in the uterus, are not limited to simple dilatation of its tissue. Its condition has experienced various alterations, dependent upon the new mode of nutrition it has assumed. The whole organ has undergone, not only extension, but inspissation of its parietes. In its unimpregnated condition, it is about four lines thick; in the third month of utero-gestation, five. Its arteries enlarge as well as its veins, which latter form large dilatations at the inner surface. These have been called *uterine sinuses.* Its nerves are greatly increased in size, as well as its lymphatics; and its proper tissue, from being hard, whitish, and incontractile, has become red, soft, spongy, and capable of energetic contraction.

A difference of sentiment has existed with regard to the nature of

the new tissue of the uterus; some comparing it to the middle coat of arteries; others describing it as partly cellular and partly muscular; but an immense majority esteeming it to be muscular. The respectable name of Blumenbach is in the minority. The facts in favour of its muscularity appear to us to be overwhelming. It is clearly so in the mammiferous animal. Thus in the rabbit, the muscularity of the uterus, according to Blundell, is far more conspicuous than that of the intestines; the fibres can be seen coarse and large, and their motion can be observed, if they be examined immediately after the rabbit is killed.

The same acute physiologist remarks, that, when developed by pregnancy, the muscularity of the organ is so clear, that if you take a portion of it, and show it to any anatomist, asking him what it is, he will unhesitatingly reply it is muscular. This experiment, he says, he once made himself. He took a portion of the unimpregnated uterus, showed it to Mr. Green and Mr. Key—"excellent judges on this point"—and, without mentioning the womb, he asked them to tell him what was the structure, when they immediately declared it to be muscular.

The arrangement of its fibres is not clearly understood. Generally, perhaps, they are described as running externally, in a longitudinal direction, from the fundus to the neck; and beneath this plane is another with circular fibres; but within this the fibres are interlaced in inextricable confusion. Some anatomists, however, enumerate as many as seven superposed planes. The fibres are of much lighter colour than those of ordinary muscles, are more like those of the bladder and intestines, and are collected in very flat and loose fasciculi.

The developement of this structure would not seem to be limited to the pregnant condition. It appears to occur whenever the uterus is increased in size, as has been remarked by Dr. Horner and by Lobstein. The muscular layers are thickest at the fundus uteri. At the cervix uteri, they are extremely small and indistinct.

After the ovum has attained the interior of the uterus, and entered the flocculent decidua, it becomes connected, in process of time, with the uterus by means of a body to be described hereafter, called the *placenta*, which is attached to the uterus, and communicates with the fœtus by a vascular cord, that enters its umbilicus.

The seat of the attachment of the placenta is not always the same. Frequently, it is near one of the cornua of the uterus; but occasionally it is implanted over the os uteri. The diversity of position has given occasion to difference of opinion, regarding the causes that influence it. By some, it has been presumed, that, in whatever part of the uterus the ovum lodges, when it quits the Fallopian tube, there an adhesion is formed. By others, it has been said, that as the ovum pushes the decidua at the mouth of the Fallopian tube before it into the uterus, the attachment of the placenta must be near the orifice of the tube. Such would, indeed, appear to be the fact

in the majority of cases, but we see so many irregularities in this respect, as to preclude us from assigning any very satisfactory reason for it.

Along with the changes that supervene in the generative apparatus during pregnancy, the whole system commonly sympathizes more or less in the altered condition. Some females, however, pass through the whole course of gestation with but very slight or no disturbance of the ordinary functions; whilst, with others, it is a period of perpetual suffering.

One of the earliest and most common signs is suppression of the catamenial discharge; but, of itself, this cannot be relied on, as it may result from disease. Soon after impregnation, the digestive and cerebral functions exhibit more or less modification. The female is affected with nausea and vomiting, especially in the morning after rising; the appetite is most fastidious; substances, which previously excited loathing being at times desired or *longed* for with the greatest avidity; whilst, on the contrary, cherished articles of diet can no longer be regarded without disgust. The sleep is apt to be disturbed; the temper to be unusually irritable, even in those possessed of signal equanimity on other occasions. The mammæ enlarge, and sometimes lancinating pains are felt in them; and a secretion of a whitish serum can often be pressed from the nipple. The areola around the nipple becomes of a darker colour in the first pregnancy than it is in the virgin state; and it is darker during each successive pregnancy than when the female is not pregnant. This appearance is one of the best single proofs of the existence of pregnancy; but it is obvious, that, for accurate discrimination, it is necessary to be aware of the hue in each particular case in the unfecundated state. Along with these signs, the uterus gradually enlarges; and, about the end of the fourth calendar month or the eighteenth week, *quickening*,—as it is usually but erroneously termed,—takes place, or the motion of the child is first felt. Prior to this,—from the moment, indeed, of a fecundating copulation,—the female is *quick* with child, but it is not until this period, that the fœtus has undergone the developement necessary for its movements to be perceptible. This occurrence establishes the fact of gestation, whatever doubts may have previously existed.

Where there is much corpulence, or where the fluid, surrounding the fœtus, is in such quantity as to throw obscurity about the case, it may be necessary, for the purpose of verifying the existence of pregnancy, to institute an examination *per vaginam.* This can rarely afford much evidence, prior to the period of quickening; but, after this, the examination, by what the French term the *mouvement de ballottement*, may indicate the presence or the contrary of a fœtus in the womb. This mode of examination consists in passing the forefinger of one hand into the vagina,—the female being in the erect attitude,—and in giving the fœtus a sudden succussion by means of the other hand placed upon the abdomen. In this way,

a sensation is communicated to the finger *in vaginâ*, which is often of an unequivocal character. During the latter months, the cervix uteri exhibits the changes depicted in figures 157, 158 and 159.

Of late years the application of the stethoscope has been used as a means of discrimination in doubtful cases. By applying this instrument to the abdomen of a pregnant female, the pulsations of the arteries of the placenta, and of the heart of the fœtus are audible; the first from the fifth month of gestation, the second a little later. This instrument may also exhibit when the pregnancy is multiple, by indicating the pulsations of two or more distinct hearts, according as the conception has been double, treble, &c.

Lastly, many uneasy feelings, attendant upon gestation, are owing to the increased size of the uterus. These occur more particularly during the latter half of pregnancy. The parietes of the abdomen may not yield with the requisite facility, so that pain may be experienced, especially at the part where the soft parietes join the false ribs. The pressure of the uterus upon the vessels and nerves of the lower extremities occasions enlargement of the veins of the legs; transudation of the serous part of the blood into the cellular tissue, so as to cause considerable swelling of the feet and ancles; numbness or pricking of the lower limbs and the most violent cramps, especially when the female is in the recumbent posture, so that she may be compelled to rise suddenly from bed several times in the course of the night. The same pressure, exerted on the bladder and rectum, especially during the latter months, brings on a perpetual desire to evacuate the contents of these reservoirs.

The *duration of human pregnancy* has given rise to much discussion amongst medico-legal and obstetrical writers; and opinions still fluctuate largely. In the years 1825--6, a case occurred before the House of Lords, which exhibits this discordance in a striking point of view. It was the Gardner Peerage cause, in which the principal accoucheurs of the British metropolis were examined,—including Sir Charles M. Clarke, Drs. Blegborough, D. Davis, A. B. Granville, Conquest, Merriman, Hopkins, Blundell, and Power. Of seventeen medical gentlemen, who gave evidence, five maintained the opinion, that the period of human utero-gestation is limited to about nine calendar months,—from thirty-nine to forty weeks, or from two hundred and seventy to two hundred and eighty days,—and of course considered it to be an impossibility that the claimant could have been the product of a three hundred and eleven day's gestation. On the other side, of twelve medical gentlemen, all of whom appeared to agree that nine calendar months is the usual term of utero-gestation, most of them maintained the possibility, that pregnancy might be protracted to nine and a half, ten, or even eleven calendar months, and were, of course, in favour of the claimant in the cause.

The difficulty, which arises in fixing upon the precise term, is owing to the impracticability, in ordinary cases, of detecting the

time of conception. The sensations of the female are most fallacious guides; and accordingly, as has been previously remarked, she is usually in the habit of reckoning from ten days after the disappearance of the catamenia; but it is manifest, that impregnation might have taken place on the very day after their cessation, or not until a day prior to the subsequent period; so that, in this way, an error of at least ten days might occur in the estimation; and again, it does not *always* happen, that the menstruation, immediately succeeding, is arrested. The period of quickening, which generally happens about the eighteenth week of utero-gestation, does not afford us more positive evidence, seeing that it is liable to vary; being experienced by some females much earlier, and, by others, somewhat later. We are, however, justified in stating, that the ordinary duration of human pregnancy is *forty weeks;* but we have no less hesitation in affirming, that it may be protracted, in particular cases, much beyond this. We find in animals, where the date of impregnation can be rigidly fixed, that, whilst the usual term can be determined without difficulty, numerous cases are met with in which the period is protracted, and there is no reason to doubt, that the same thing happens occasionally to the human female.

In a case detailed by Dr. Dewees, an opportunity occurred for dating with precision the time of fecundation. The case is, likewise, interesting in another respect, as demonstrating, that fecundation does not necessarily arrest the succeeding catamenial discharge. The husband of a lady, who was obliged to absent himself many months, in consequence of the embarrassment of his affairs, returned one night clandestinely; his visit being known only to his wife, her mother, and Dr. Dewees himself. The lady was, at the time, within a week of her menstrual period; and, as the catamenia appeared as usual, she was induced to hope, that she had escaped impregnation. Her catamenia did not, however, make their appearance at the next period; the ordinary signs of pregnancy supervened; and in nine months and thirteen days, or in two hundred and ninety-three days from the visit of the husband, she was delivered.

In his evidence before the House of Peers, in the case just alluded to, Dr. Granville stated his opinion, that the usual term of utero-gestation is as we have stated it; but he, at the same time, detailed the case of his own lady, in whom it had been largely protracted. Mrs. Granville passed her menstrual period on the 7th of April, and on the 15th of August following she quickened;—that is, four months and six or seven days afterwards. In the early part of the first week in January, her confinement was expected, and a medical friend desired to hold himself in readiness to attend. Labour pains came on at this time, but soon passed away; and Mrs. G. went on till the 7th of February, when labour took place, and the delivery was speedy. The child was larger and stronger than usual, and was considered by Dr. Granville,—as well as by Dr. A. T. Thom-

son, the Professor of Materia Medica in the University of London,—as a ten months child.

If, in this case, we calculate, that conception occurred only the day before the interruption of menstruation, three hundred and six days must have elapsed between impregnation and birth; and if we take the middle period between the last menstruation and the interruption, the interval must have been three hundred and sixteen, or three hundred and eighteen days.

The limit, to which the protraction of pregnancy may *possibly* extend, cannot be assigned. It is not probable, however, that it ever varies largely from the ordinary period. The University of Heidelberg allowed the legitimacy of a child, born at the expiration of thirteen months from the date of the last connubial intercourse; and a case was decided by the Supreme Court of Friesland, by which a child was admitted to the succession, although it was not born till three hundred and thirty-three days from the husband's death; or only a few days short of twelve lunar months. These are instances of the *ne plus ultra* of judicial philanthropy, and, perhaps we might say, credulity. Still, although extremely improbable, we cannot say that they are impossible. This much, however, is clear, that real excess over two hundred and eighty days is by no means frequent; and we think, in accordance with the civil code now in force in France, that the legitimacy of an infant born three hundred days after the dissolution of marriage may be contested; although we are by no means disposed to affirm, that if the character of the woman be irreproachable, the decision should be on the side of illegitimacy.

At the end of seven months of utero-gestation, and even a month earlier, the fœtus is capable of an independent existence; provided, from any cause, delivery should be hastened. This is not, however, the *full period*, and although labour may occur at the end of seven months, the usual course is for the fœtus to be carried until the end of nine calendar months. If the fœtus is extruded prior to the period at which it is able to maintain an independent existence, the process is termed *abortion* or *miscarriage;* if between this time and the full period, it is called *premature labour.*

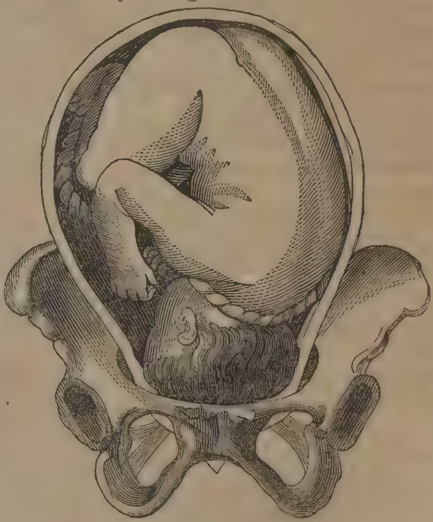
With regard to the causes, that give rise to the extrusion, we are in utter darkness. It is in truth as inexplicable as any of the other instinctive operations of the living machine. Yet although this is generally admitted, the discussion of the subject occupies a considerable space in the works of some obstetrical writers. Our knowledge appears to be limited to the fact, that when the fœtus has undergone a certain degree of developement, and the uterus a corresponding distention, its contractility is called into action, and the uterine contents are beautifully and systematically expelled. Nor can we always fix upon the degree of distention, that shall give occasion to the exertion of this contractile power. Sometimes, it will

supervene after a few months of utero-gestation so as to produce abortion; at other times it will happen when the fœtus is just *viable;* and at others, again, and in the generality of cases, it is not elicited until the full period. In cases of twins, the uterus will admit of still greater distention before its contractility is aroused.

A day or two preceding labour, a discharge is occasionally observed from the vagina of a mucous fluid, more or less streaked with blood. This is termed the *show*, because it indicates the commencement of some dilatation of the neck, or mouth of the womb,—the forerunner of *labour* or *travail.*

The external organs, at the same time, become tumid and flabby. The orifice of the uterus, if an examination be made, is perceived to be enlarging; and its edges are thinner. Along with this, slight grinding pains are experienced in the loins and abdomen. After an uncertain period, pains of a very different character come on, which commence in the loins, and appear to bear down towards the os uteri. These are not constant, but recur, at first after long intervals, and subsequently after shorter;—the body of the uterus manifestly contracting with great force, so as to press the ovum down against the mouth of the womb, and to dilate it. In this way, the membranes of the ovum protrude through the os uteri with their contained fluid, the pouch being occasionally termed the *bag of waters.* Sooner or later the membranes give way, the *waters* are discharged, and the uterus contracts so as to embrace the body of the child, which was previously impracticable, except through the medium of the liquor amnii.

Fig. 160.



Natural labour.

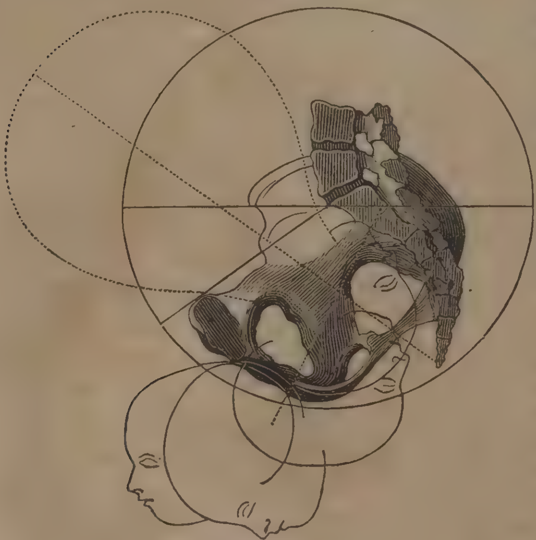
At the commencement of labour, the child's head has not entered the pelvis, the occiput, as in the marginal figure, being generally towards the left acetabulum; but, when the uterine contractions become more violent, and are accompanied by powerful efforts on the part of the abdominal muscles, the head enters the pelvis, the mouth of the womb becomes largely dilated, and the female is in a state of agitation and excitement, owing to the violence of the efforts, and the irresistible desire she has of assisting them as far as lies in her power. When the head has entered the pelvis, in the position described, in which the long diameter corresponds to the

long diameter of the pelvis, it describes, laterally, an arc of a circle, the face passing into the hollow of the sacrum, and the occiput behind the arch of the pubis, as in Fig. 161. By the continuance of the pains, the head presents at the vulva. The pains now become most urgent and forcing. The os coccygis is pushed backwards, and the perineum is distended,—at times so considerably, as to threaten, and even to effect laceration; the anus is also forced open and protruded; the nymphæ and carunculæ of the vagina are effaced; the labia separated, and the head clears the vulva, from the occiput to the chin, experiencing a vertical rotation as depicted in Fig. 162. When the head is extruded, the shoulders and rest of the body readily follow, on account of their smaller dimensions. The child, however, still remains attached to the mother by the navel-string, which has to be tied, and divided at a few fingers' breadth from the umbilicus.

Fig. 161.

Head of the fœtus in the pelvis.

Fig. 162.



Extrusion of the head.

After the birth of the child, the female has generally a short interval of repose; but, in a few minutes, slight bearing down pains are experienced, owing to the contraction of the uterus for the separation of the placenta, and of the membranes of the ovum, called the *secundines* or *after-birth.*

The process of parturition is accomplished in a longer or shorter time, in different individuals, and in the same individual in different labours, according to the particular conditions of the female and fœtus. The parts, however, when once dilated, yield much easier afterwards to similar efforts, so that the first labour is generally the most protracted.

After the separation of the secundines, the female is commonly left in a state of debility and fatigue; but this gradually disappears. The uterus also contracts; its vessels become tortuous, small, and their orifices are plugged up. For a short time, blood continues to be discharged from them; but, as they become obliterated by the return of the uterus to its usual size, the discharge loses its sanguineous character, and is replaced by one of a paler colour, called the *lochia*, which gradually disappears, and altogether ceases in the course of two or three weeks after delivery.

For a day or two after delivery, coagula of blood form in the interior of the uterus, especially in the second and subsequent labours, which excite the organ to contraction for their expulsion. These contractions are accompanied with pain, and are called *after-pains;* and as their object is the removal of that, which interferes with the return of the uterus to its proper dimensions, it is obvious that they ought not to be officiously interfered with.

Whilst the uterus is contracting its dimensions, the other parts gradually resume the condition they were in prior to delivery; so that, in the course of three or four weeks, it is impracticable to pronounce positively, whether delivery has recently taken place or not.

Fig. 163.

Breech presentation.

Labour, as thus accomplished, is more deserving of the term in the human female than in animals; and this is partly owing to the large size of the fœtal head, and partly to the circumstance, that in the animal the axis of the pelvis is the same as that of the body, whilst, in the human female, the axis of the brim, as represented by the dotted straight lines in Fig. 162, forms a considerable angle with that of the outlet.

The position of the child, exhibited in Fig. 160,—with the face behind and the occiput before,—constitutes the usual presentation in natural labour. Of twelve thousand six hundred and thirty-three

children, born at the *Hospice de la Maternité* of Paris, twelve thousand one hundred and twenty, according to M. Jules Cloquet, were of this presentation; sixty-three had the face turned forward; one hundred and ninety-eight were breech presentations; (see Fig. 163;) in one hundred and forty-seven cases, the feet presented; and in three, the knees. All these, however, are cases, in which labour can be effected without assistance;—the knee and feet presentations being identical, as regards the process of delivery, with that of the breech. But, whenever any other part of the fœtus presents, the position is unfavourable, and requires that the hand should be introduced into the uterus, with the view of bringing down the feet, and converting the case into a foot presentation.

The following table, drawn up from data furnished by Velpeau, will show the comparative number of presentations, according to the experience of the individuals mentioned.

TABLE

EXHIBITING THE RATIO OF PRESENTATIONS IN 1000 CASES.

	ACCORDING TO							
	Merriman	Bland	Madame Boivin	Madame Lachapelle	Nägele	Lovati	Hospital of the Faculté	Boër
Regular, or of the vertex,	924	944	969	933	933	911	980	
I. *Occipito anterior*,	908		944	910		895		
a. Occipito-cotyloid (left)			760	717		537		
Do. (right)			179	209				
b. Occipito-pubian,			0.29					
II. *Occipito-posterior*,			9.4	9				
a. Fronto-cotyloid (left)			5.3	7.3				
b. Do. (right)			4.4	2.9				
Face presentation,	2.2	2.6	3.6	4.6				8.8
Mento-iliac (right)				2.6				
Of the pelvis,	36	28	29	36	47			29
Of the foot,	12.7	9.4		14				10.3
Of the knees,			0.19	0.40				
Of the breech,	23	13	18	22				19
Of the trunk,			4.6	5.3	4.8			
Requiring Forceps,	6.6	4.7	4.6	3.4	36			5.7
——— Turning,	16	4.7		7.8	7.2			5.9
——— Cephalotomy,	3.3	5.2	4.77	0.53	2.4			1.5

The parturient and child-bed condition is not devoid of danger to the female: yet the mortality is less than is generally, perhaps, imagined. The number of deaths, during labour and subsequently—connected therewith, has been stated to be of late in Berlin as 1 in 152; in Königsberg, as 1 in 168; and in Wirtemberg, as 1 in 175; a proportion much less than during the last century.

The further details of this subject belong more appropriately to obstetrics.

When the child has been separated from the mother, and continues to live by the exercise of its own vital powers, it has still to be dependent upon her for the nutriment adapted to its tender condition. Whilst in utero this nutriment consisted of fluids placed in contact with it, but, after birth, a secretion serves this purpose, which has to be received into the stomach and undergo the digestive process. This secretion is the *milk.* It is prepared by the *mammæ* or *breasts*, the number, size, and situation of which are characteristic of the human species. Instances are, however, on record of three or more distinct mammæ in the same individual. Two such cases are described by Dr. G. C. M. Roberts, of Baltimore. At times, two nipples are met with on one breast. Three cases of the kind are given by Tiedemann. In some instances, the supernumerary breasts have been on other parts of the body.

Each breast contains a mammary gland, surrounded by the fat of the breast, and resting on the pectoralis major muscle. It is formed of several lobes, united by a somewhat dense, cellular tissue, and consisting of smaller lobules, which seem, again, composed of round granulations, of a rosy-white colour, and of about the size of a poppy seed. The glandular granula give origin to the excretory ducts, called *tubuli lactiferi* or *galactophori*, which are tortuous, extensible, and transparent. These enlarge and unite with each other, but so that those of each lobe remain distinct from, and have no communication with, the ducts of any other lobe. All these finally terminate in sinuses, near the base of the nipple, which are fifteen or eighteen in number, and open on the nipple, without having communication with each other.

The size and shape of the breast are chiefly caused by the cellular tissue in which the mammary gland is situated: this is covered by a thin layer of skin, which is extremely soft and delicate, and devoid of folds. In the middle of the breast is the tubercle, called the *nipple*,—a prominence consisting of an erectile spongy tissue, differing in colour from the rest of the breast,—and around it is the *areola*, which is of a rosy hue in youth, but becomes darker in the progress of life, and the capillary system of which is so delicate as to blush, like the countenance, under similar emotions. The changes, produced on the areola by gestation, have been already described. The skin, at the base of the nipple, and on its surface, is rough, owing to the presence of a number of sebaceous follicles, which secrete a fluid for the lubrication of the part, and for defending it from the action of the secretions of the mouth of the infant during lactation. Numerous arteries, veins, nerves and lymphatics,—the anatomical constituents of organic textures in general,—also enter into the composition of the mammæ and nipples.

The secretion of milk is liable to longer intermissions than any other function of the kind. In the unmarried and chaste female, although the blood, whence milk is formed, may be constantly

passing to the nipple, no secretion takes place from it. It is only during gestation and for some time afterwards, as a general rule, that the necessary excitation exists to produce it. Yet although largely allied to the generative function,—the mammæ undergoing their chief developement in puberty and becoming shrivelled in old age,—the secretion may arise independently of impregnation; for it has been witnessed in the unquestionable virgin, in the superannuated female, and even in the male sex. The fact as regards the unimpregnated female is mentioned by Hippocrates. Baudelocque states, that a young girl at Alençon, eight years old, suckled her brother for the space of a month. Dr. Gordon Smith refers to a manuscript in the collection of Sir Hans Sloane, which gives an account of a woman, at the age of sixty-eight, who had not borne a child for more than twenty years, and who nursed her grandchildren, one after another. Professor Hall, of the University of Maryland, related to the Author the case of a widow, aged 50, whom he saw giving suck to one of her grandchildren, although she had not had a child of her own for twenty years previously. The secretion of milk was solicited by putting the child to her breast during the night, whilst weaning it. Dr. Francis, of New York, describes the case of a lady, who, fourteen years previously, was delivered of a healthy child after a natural labour. "Since that period," he remarks, "her breasts have regularly secreted milk in great abundance, so that, to use her own language, she could at all times easily perform the office of a nurse:" and Dr. Kennedy, of Ashby-de la Zouch, has described the case of a woman, who menstruated during lactation, suckled children uninterruptedly through the full course of forty-seven years, and, in her eighty-first year, had a moderate, but regular supply of milk, and this rich, and sweet, and not differing from that yielded by young and healthy mothers.—But these, and cases of a similar nature, of which there are many on record, do not possess the same singularity as those of the function being executed by the male. Yet we have the most unquestionable authority in favour of the occurrence of such instances. The Bishop of Cork relates a case in the *Philosophical Transactions* for 1741, of a man who suckled his child after the death of his wife. Humboldt adduces one of a man, thirty-two years of age, who nursed his child for five months on the secretion from his breasts; Captain Franklin, in his "*Journey to the shores of the Polar Sea,*" gives a similar instance; and Professor Hall, of the University of Maryland, exhibited to his obstetrical class, in the year 1827, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ, rather more conical than those of the female, and projecting fully seven inches from the chest; with perfect and large nipples. The glandular structure seemed to the touch to be exactly like that of the female. This man, according to Professor Hall, had officiated as wet-nurse, for several years, in the family of his mistress, and he represented, that the secretion of milk was induced by applying the

children, entrusted to his care, to the breasts, during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. His genital organs were fully developed.

It appears, therefore, that the secretion of milk *may* be caused, independently of a uterus, by soliciting the action of the mammary glands, but that this is a mere exception to the general rule, according to which the secretion is as intermittent as gestation itself.

We have noticed, as one of the signs of pregnancy, that the breasts become enlarged and turgid, denoting the aptitude for the formation of the fluid; and it not unfrequently happens that, towards the middle and latter periods of pregnancy, milk will distil from the nipples. This fluid, however, as well as that which flows from the breasts during the first two or three days after delivery, differs somewhat from milk, containing more serum and butter, and less caseum, and it is conceived to be more laxative, so as to aid the expulsion of the meconium. This first milk is called *colostrum*, *protogàla*, &c., and, in the cow, constitutes the *biestings* or *beastings*. Generally, about the third day after confinement, the mammæ become tumid, hard, and even painful, and the secretion from this time is established, the pain and distention soon disappearing.

It is hardly necessary to discuss the views of Richerand, who considers the milk to be derived from the lymph; of others who derive it from the chyle; of Raspail, who is disposed to think, that the mammary glands are in connexion, by media of communication yet unknown, with the mucous surface of the stomach, and that they subtract, from the alimentary mass, the salts and organizing materials which enter into the composition of the milk; or of Girard of Lyons, who gratuitously asserts, that there is in the abdomen an apparatus of vessels,—intermediate between the uterus and mammæ,—which continue inactive, except during gestation, and for some time after delivery, but, in those conditions, are excited to activity. All these notions are entirely hypothetical, and there is no reason for believing, that this secretion differs from others, as regards the kind of blood from which it is separated. The separation takes place in the tissue of the gland, and the product is received by the lactiferous ducts, along which it is propelled by the fresh secretion continuously arriving, and by the contractile action of the ducts themselves, the milk remaining in the ducts and sinuses, until the mammæ are, at times, considerably distended and painful.

The excretion of the milk takes place only at intervals. When the lactiferous ducts are sufficiently filled, a degree of distention and uneasiness is felt, which calls for the removal of the contained fluid. At times, the flow occurs spontaneously; but, commonly, only when solicited either by sucking or drawing the breast, the secretion under such circumstances being very rapid, and the contraction of the galactophorous ducts such, as to project the milk through the orifices in a thready stream.

Milk is a highly azoted fluid, composed of water, caseum, sugar of milk, certain salts,—as the muriate, phosphate, and acetate of potassa, with a vestige of lactate of iron and earthy phosphate,—and a little lactic acid. According to Berzelius, cow's milk consists of cream, and milk properly so called,—the *cream* consisting of butter, 4.5; cheese, 3.5; whey, 92.0;—and the *whey*, of milk and salt, 4.4;—the *milk* containing water, 928.75;—cheese, with a trace of butter, 28.01; sugar of milk, 35.00; muriate of potassa, 1.70; phosphate of potassa, 0.25; lactic acid, acetate of potassa, and lactate of iron, 6.00; and phosphate of lime, 0.30.

Raspail defines milk to be an aqueous fluid, holding albumen and oil in solution, by means of an alkali, or alkaline salt, which he suggests may be the acetate of ammonia,—and, in suspension, an immense number of albuminous and oleaginous globules. The following table exhibits the discrepant results of the investigations of Brisson, Boyssou, Stipriaan Luiscius and Bondt, Schübler, and John, in 1000 parts of the milk of different animals—as given by Burdach.

	Observers.	Specific gravity.	Butter.	Cheese.	Sugar of milk.	Water.	Extract.
Ewe's milk.	Brisson,	10409					
	Boyssou,		38.24	51.26	20.73	886.19	3.45
	Luiscius,	10350	58.12	153.75	41.87	746.25	
	John,		54.68	31.25	39.06	875.00	
Cow's milk.	Brisson,	10324					
	Boyssou,		24.88	39.40	31.33	900.92	3.45
	Luiscius,	10280	26.87	89.37	30.62	853.12	
	Schübler,		24.00	50.47	77.00	848.53	
	John,		23.43	93.75	39.06	843.75	
Goat's milk.	Brisson,	10341					
	Boyssou,		29.95	52.99	20.73	892.85	3.45
	Luiscius,	10360	45.62	91.25	43.75	819.37	
	John,		11.71	105.45	23.43	849.39	
Mare's milk.	Brisson,	10364					
	Boyssou,		0.57	18.43	32.25	938.36	10.36
	Luiscius,	10450	0.00	16.25	87.50	896.25	
	John,		0.00	64.84	35.15	900.00	
Ass's milk.	Brisson,	10355					
	Boyssou,		0.92	19.58	39.97	932.60	6.91
	Luiscius,	10230	0.00	33.12	45.00	921.87	
	John,		0.00	11.71	46.87	941.40	
	Brisson,	10203					
	Boyssou,		32.25	11.52	46.08	903.92	6.91
	Luiscius,	10250	30.00	26.87	73.12	870.00	
	John,		23.43	15.62	39.06	921.87	

From this table, an approximation may be made, as to the main differences between the milk of those different animals, but it is not easy to explain the signal discrepancy amongst observers as to the

quantity of the different materials in the milk of the same animal. Much, of course, may be dependent upon the state of the milk at the time of the experiment, but this can scarcely account for the whole discrepancy.

From a great number of experiments, MM. Deyeux and Parmentier classed six kinds of milk, which they examined, according to the following table, as regards the relative quantity of the materials they contained.

Caseum.	Butter.	Sugar of milk.	Serum.
Goat. Sheep. Cow.	Sheep. Cow. Goat.	Woman. Ass. Mare.	Ass. Woman. Mare.
Ass. Woman. Mare.	Woman. Ass. Mare.	Cow. Goat. Sheep.	Cow. Goat. Sheep.

Human milk, therefore, contains more sugar of milk and less cheesy matter than that of the cow; hence it is sweeter, more liquid, less coagulable, and incapable of being made into cheese. Its quantity and character differ according to the quantity and character of the food,—a circumstance, which was one of the greatest causes of the belief, that the lymphatics or chyliferous vessels convey to the mammæ the materials for the secretion. The milk is, however, situated in this respect like the urine, which varies in quantity and quality, according to the amount and kind of solid or liquid food taken. The milk is more abundant, thicker, and less acid, if the female lives on animal food, but possesses the opposite qualities when vegetable diet is used. It is apt, also, to be impregnated with heterogeneous matters, taken up from the digestive canal. The milk and the butter of cows indicate unequivocally the character of their pasturage, especially if they have fed on the turnip, wild onion, &c. Medicine, given to the mother, may in this way act upon the infant. Serious—almost fatal—narcotism was induced in the infant of a professional friend of the Author, by a dose of morphine administered to his wife.

The quantity of milk secreted is not always in proportion to the bulk of the mammæ: a female whose bosom is of middle size often secretes more than another in whom it is much more developed;—the greater size being usually owing to the larger quantity of adipous tissue surrounding the mammary gland, and this tissue is in nowise concerned in the function.

The secretion of milk usually continues until the period, when the organs of mastication of the infant have acquired the necessary developement for the digestion of solid food: it generally ceases

during the second year. For a great part, or the whole of this time, the menstrual flux is suspended; and if both the secretions,—mammary and menstrual—go on together, the former is usually impoverished and in small quantity. Whilst lactation continues, the female is less likely to conceive; and hence the importance,—were there not even more weighty reasons,—of the mother's suckling her own child, in order to prevent the too rapid succession of children. From observations, made at the Manchester Lying-in Hospital, on one hundred and sixty married women, Mr. Roberton concludes, that in seven out of eight women, who suckle for as long a period as the working classes in England are in the habit of doing—about fifteen and a half months on the average—there will be an interval of fifteen months between parturition and the commencement of the subsequent pregnancy;—and that, in a majority of instances, when suckling is prolonged to even nineteen or twenty months, pregnancy does not take place till after weaning. When menstruation recurs during suckling, it is an evidence that the womb has, again, the organic activity, that befits it for impregnation.

OF FŒTAL EXISTENCE—EMBRYOLOGY.

The subject of fœtal existence forms so completely a part of the function we are considering, that its investigation naturally succeeds that of the part performed by the parents in its production; and more especially as the developement of the fœtus is synchronous with all the uterine changes that have been pointed out. By most writers on physiology, it has been the custom to include this subject under the same head as gestation, but the anatomy and physiology of the fœtus have recently been so much studied as to sanction their separation.

Anatomy of the Fœtus.

The uncertainty, which hangs over the immediate formation of the new individual, has been already mentioned; and it is not necessary for us to do more than refer to the previous description of the different views regarding the predominance of the paternal or maternal influence over the character of the product of generation. The microscopical observations of Mr. Bauer, under the superintendence of Sir Everard Home, would seem to show, that the human ovum and that of the quadruped consist of a semitransparent, elastic, gelatinous substance, enveloped in two membranous coverings; that this substance is formed in the ovarium independently of the male influence, but requires the application of such influence to undergo its developements.

The period, at which the embryo is first perceptible in the ovule, differs in different animals. Haller asserts, that in sheep, whose

term of gestation is five months, he could observe nothing more than a homogeneous mucus for the first sixteen days; but, at this time, membranes seemed to envelope the ovule and to give it shape; and on the twenty-fifth day, an opaque point indicated the fœtus. Haighton, in experimenting on rabbits, could detect no change before the sixth day, and the fœtus was not perceptible till the tenth. In the case, related by Sir Everard Home, to which we have so frequently referred, the embryo was perceptible, under the microscope of Mr. Bauer, and although its weight did not probably exceed a grain, the future situation of the brain and spinal marrow was apparent. From this period, and especially after the fifteenth day, the ovule can be separated into two distinct sets of parts,—the dependencies of the fœtus, and the fœtus itself. These, in the course of pregnancy, become more and more readily separable. Each will require some consideration.

Prior to this, however, it may be well to refer to the changes that the egg undergoes during incubation; where we have an opportunity of observing the transmutations at all periods of fœtal formation, independently of any connexion with either parent. The subject has engaged the attention of physiologists of all ages; but it is chiefly to those of more modern times—as Hunter, Cuvier, Dutrochet, Pander, Rolando, Sir Everard Home, MM. Prévost and Dumas, &c. that we are indebted for more precise information on the subject; although, unfortunately, they are by no means of accordance on many points. The investigations of Sir Everard Home, aided by those of the excellent microscopic observer, Mr. Bauer, are peculiarly interesting from the engravings that accompany them, some of which we shall borrow in elucidation of the following brief description.

The egg of a bird, of a hen for example, consists of two descriptions of parts;—those which are but little concerned in the developement of the new being, and which remain after the chick is hatched,—as the shell and the membrane lining it,—and such as undergo changes along with those of the chick and co-operate in its formation,—as the white, the yolk, and the cicatricula or molecule. The shell is porous, to allow of the absorption of air through it; and of the evaporation of a part of the albumen or white. In the ovarium it is albuminous, but in the cloaca becomes calcareous. The membrane, *membrana albuminis*, that lines the shell, is of a white colour, and consists of two layers, which separate from each other at the greater end of the egg, and leave a space filled with air, owing to the evaporation of the white and the absorption of air. This space is larger the older the egg. The white does not exist whilst the egg is attached to the ovary. It is deposited between the yolk and the shell as the egg passes through the oviduct. Of the white there are two distinct kinds;—the outermost, thin and fluid, which evaporates in part, and is less abundant in the old than in the fresh

laid egg, and another, situated within the last, which is much denser, and only touches the shell at the smaller extremity of the egg by a prolongation of its substance, which has been called the *ligament of the white.* The yolk seems to be, at first sight, a semifluid mass without organization; but on closer examination, it is found to consist of a yolk-bag, two *epidermic* membranes, which envelope it as well as the cicatricula or molecule. Two prolongations of these membranes, knotty, and terminating in a flocculent extremity in the albumen, called *chalazes*, or *poles*, are attached to the two ends of the egg and thus suspend it. It is also surrounded by a proper membrane; and lastly, under the epidermic coats of the yolk, and upon its proper coat lies the *cicatricula*, *macula*, *tread of the cock*, or *gelatinous molecule* from which the future embryo is to be formed. It is found before the yolk leaves the ovarium.

The external membrane of the yolk, when it quits the yolk-bag, is very thin and delicate; its surface is studded over with red dots, which disappear in its passage along the oviduct. When this membrane is removed, there is a natural aperture in the thick, spongy covering under it, through which is seen the cicatricula or molecule, surrounded by an *areola*, *halo* or *circulus.* On examination, this areola proves to be nothing more than that part of the surface of the yolk, which is circumscribed by the margin of the aperture.

Fig. 164.

Ovarium of laying hen, natural size. The ova at different stages of increment.

The molecule or cicatricula itself, Fig. 164, has a granulated appearance; and, according to Sir Everard Home, is made up, in the centre, of globules $\frac{1}{2800}$th part of an inch in diameter, surrounded by circles of a mixed substance; about two-thirds consisting of the same small

globules, and one-third of larger oval globules, about $\frac{1}{1600}$th part of an inch in diameter; the last resembling in shape the oval red globules of the blood in the bird. Besides the globules, there is some fine oil, which appears in drops, when the parts are immersed in water. Oval globules and oil are also met with in the yolk itself, but in small proportion and devoid of colour.

Fig. 165.

New-laid egg, with its molecule, &c.

When the egg leaves the ovarium, Fig. 164, the egg ovarial yolk-bag gives way at the median line, and the yolk drops into the commencement of the oviduct. The yolk-bags are exceedingly vascular, the outer membrane of the yolk being connected to them by vessels and fasciculi of fibres, but being readily separable from them. During the first hours of incubation no change is perceptible in the egg, but, about the seventh, the molecule is evidently enlarged, and a membrane, containing a fluid substance is observable. This membrane is the *amnion.* At this time a white line is perceptible in the molecule, which is the rudimental fœtus; and, even at this early period, according to Sir Everard Home, the brain and spinal marrow can be detected. The areola has extended itself; and the surface, beyond the line which formed its boundary, has acquired the consistence of a membrane, and has also a distinct line by which it is circumscribed. This Sir Everard calls the *outer areola.* In the space between these two areolæ are distinct dots of an oily matter.

Fig. 166.

Egg, thirty-six hours after incubation.

In twelve hours, the rudiments of the brain are more distinct, as well as those of the spinal marrow. In thirty-six hours, the head is turned to the left side. The cerebrum and cerebellum appear to be distinct bodies. The iris is perceptible through the pupil. The intervertebral nerves are nearly formed; those, nearest the head, being the most distinct. A portion of the heart is seen.

At this period, under the inner areola, apparently at the termination of the spinal marrow, a *vesicle* begins to protrude, which is seen earlier in some eggs than in others. The white of egg is found to be successively absorbed by the yolk, so that the latter is rendered more fluid and its mass augmented. The first appearance of red blood is discerned on the surface of the yolk-bag towards the end of the second day. A series of points is observed, which form grooves; and these closing constitute vessels, the trunks of which become connected with the chick. The vascular surface itself is called *figura venosa* or *area vasculosa;* and the vessel, by which its margin is defined, *vena terminalis.* The trunk of all the veins joins the vena portæ, whilst the arteries, that ramify on the yolk-bag, arise from the mesenteric artery of the chick, and have hence been called *omphalo-mesenteric.*

In two days and a half, the spinal marrow has its posterior part inclosed: the auricles and ventricles of the heart are perceptible, and the auricles are filled with red blood. An arterial trunk from the left ventricle gives off two large vessels,—one to the right side of the embryo, the other to the left;—sending branches over the whole of the areolar membrane, which is bounded on each side by a large trunk carrying red blood; but the branches of the two trunks do not unite, there being a small space on one side, which renders the circle incomplete. This Sir Everard Home calls the areolar circulation.

In three days, the outer areola has extended itself over one-third of the circumference of the yolk, carrying the marginal arteries along with it to the outer edge but diminished in size. The brain is much enlarged; the cerebellum being still the larger of the two. The spinal marrow and its nerves are most distinctly formed; and the eye appears to want only the pigmentum nigrum. The right ventricle of the heart contains red blood: the arteries can be traced to the head: the rudiments of the wings and legs are formed, and the vesicle is farther enlarged, but its vessels do not carry red blood. It has forced its way through the external covering of the yolk, and opened a communication through this slit, by which a part of the albumen is admitted to mix itself with the yolk, and gives it a more oval form. At this period, the embryo is generally found to have changed its position and to be wholly turned on the left side.

Fig. 167.

Egg, opened three days after incubation.

In four days, the vesicle is more enlarged, and more vascular, its

vessels containing red blood. The optic nerve and pigmentum nigrum of the eye are visible. The outer areola extends half over the yolk, with which a larger portion of the white is now mixed.

In five days, the vesicle has acquired a great size, and become exceedingly vascular; the yolk too has become thinner, in consequence of its admixture with more of the albumen.

Fig. 168.

Egg, five days after incubation.

In six days, the vascular membrane of the areola has extended farther over the yolk. The vesicle, at this time, has suddenly expanded itself in the form of a double night-cap over the yolk, and its coverings are beginning to inclose the embryo, the outermost layer being termed the *chorion*, the innermost the *middle membrane*. The amnion contains a fluid, in which the embryo is suspended by the vessels of the vesicular membrane. The brain has become enlarged so as to equal in size the body of the embryo. Its vessels are distinctly seen. The two eyes equal the whole brain in size. The parietes of the thorax and abdomen have begun to form; and the wings and legs are nearly completed, as well as the bill. At this period muscular action has been noticed.

Fig. 169.

Egg, ten days after incubation.

In seven days, the vesicle,—having extended over the embryo,—has begun to inclose the areolar covering of the yolk, and a pulsation is distinctly seen in the trunk that supplies the vesicular bag with blood. The pulsations were, in one case, seventy-nine in a minute, whilst the embryo was kept in a temperature of 105°; but when the temperature was diminished, they ceased, and when again raised to the same point, the pulsation was reproduced. The muscles of the limbs now move with vigour.

In eight days, the anastomosing branches of the vesicular circulation have strong pulsation in them.

In nine days, the vesicle has nearly inclosed the yolk.

In ten days, no portion of the yolk is observable on the outside of the vesicle.

Fig. 170.

Embryo of the egg, showing the opening in the abdomen, from which portions of the vesicular and areolar membranes and turns of the intestines are protruding. Magnified two diameters.

The embryo being taken out of the amnion,—now become full of water,—the thorax is found to be completely formed, and the roots of the feathers very distinct.

The contents of the egg, during the formation of the embryo, become much diminished in quantity, and the void space is gradually occupied by a gas, which was examined by Mr. Hatchett, and found to be atmospheric air, deposited at the great end of the egg between the layers of the membrane lining the shell. Even prior to incubation, there is always a small portion of air in this place, which is supposed to be employed in aerating the blood, from the time of its first acquiring a red colour, till superseded in that office by the external air acting through the eggshell upon the blood in the vessels of the vesicular membrane, with which it is lined.

Fig. 171.

Embryo eighteen days old.—Half the natural size.

Between the period of fourteen and eighteen days, the yolk becomes completely inclosed by the areolar membrane; and, at the expiration of the latter period, the greater part of the yolk is drawn into the body, as in the marginal figure. At twenty days, the chick is completely formed, the yolk is entirely drawn in, and only portions of the membrane belonging to the vesicle are seen externally. The yolk-bag has a narrow tube, half an inch long, connecting it to the intestine, eight inches above the openings of the cæca into the gut.

The whole of these changes, which in the viviparous animal are effected within the womb of the mother, take place in the incubated chick by virtue of its own powers; and without any

assistance, except that of the atmospheric air and of a certain degree of warmth. In the course of incubation the yolk becomes constantly thinner and paler, by the admixture of the white; and, at the same time, innumerable fringe-like vessels, with flocculent extremities, of a singular structure, form on the inner surface of the yolk-bag, and hang into the yolk. The office of these is presumed to be, to absorb the yolk and to convey it into the veins of the yolk-bag, where it is assimilated to the blood and applied to the nutrition of the new being. Blumenbach states, that in numerous and varied microscopical examinations of the yolk-bag, in the latter weeks of incubation, he thinks he has observed the actual passage of the yolk from the yellow flocculent vessels of the inner surface of the bag into the blood-vessels which go to the chick. He has, at all events, seen manifest yellow streaks in the red blood contained in those veins. When the chick has escaped from the shell, the yolk, we have seen, is not exhausted, but is received into the abdomen, and as it communicates with the intestinal tube, it is for some time a source of supply to the young animal, until its strength is equal to the digestion of its appropriate food. The highly vascular chorion is manifestly an organ of aeration, like the placenta of the mammalia.

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1. *DEPENDENCIES OF THE FŒTUS.*—These are the parts of the ovum, that form its parietes, attach it to the uterus, connect it with the fœtus, and are inservient to the nutrition and developement of the new being.

They consist,—*First*, of two membranes, according to common belief, which constitute the parietes of the ovule, and which are concentric; the outermost, called the *chorion*, the innermost, filled with a fluid, in which the fœtus is placed, and called the *amnion* or *amnios*. By Boër and Granville, a third and outer membrane has been admitted the *cortical membrane* or *cortex ovi*. *Secondly*, of a spongy, vascular body, situate without the chorion, covering about one-quarter of the ovule, and connecting it with the uterus,—the *placenta*. *Thirdly*, of a cord of vessels,—extending from the placenta to the fœtus, the body of which is penetrated at the umbilicus, by the vessels,—called the *umbilical cord* or *navel string*, and *lastly*, of three vesicles—the *umbilical*, *allantoid*, and *erythroid*, which are considered, by many, to be concerned in fœtal nutrition.

1. The *chorion* or *endochorion* is the outermost of the membranes of the ovule. About the twelfth day after conception, according to Velpeau, it is thick, opaque, resisting, and flocculent at both surfaces. These flocculi, in the part of the ovum that corresponds to the tunica decidua reflexa, aid its adhesion to that membrane; but, in the part where the ovum corresponds to the uterus, they become developed to constitute the placenta. At its inner surface, the chorion corresponds to the amnion. These two membranes are, however, separated during the earliest period of fœtal existence, by a serous fluid;

but, at the expiration of three months, the liquid disappears and they are afterwards in contact.

By many anatomists, the chorion is conceived to consist originally of two laminæ: Velpeau denies this, and asserts, that he has never been able to separate them, even by the aid of previous maceration.

As the placenta is formed on the uterine side of the chorion, the membrane is reflected over the fœtal surface of that organ, and is continued over the umbilical cord, as far as the umbilicus of the fœtus, where it is confounded with the skin, of which it consequently appears to be a dependence. As pregnancy advances, the chorion becomes thinner, and less tenacious and dense, so that at the full period, it is merely a thin, transparent, colourless membrane, much more delicate than the amnion.

Haller, Blumenbach and Velpeau affirm it to be devoid of vessels; but, according to Wrisberg, it receives some from the umbilical trunks of the fœtus, and, according to others, from the decidua. Dutrochet conceives it to be an extension of the fœtal bladder. Its vascularity, according to Dr. Granville, is proved by its diseases, which are chiefly of an inflammatory character, ending in thickening of its texture; and he affirms, that there is a preparation in the collection of Sir Charles Clarke, which shows the vessels of the chorion as evidently as if they were injected.

2. The *amnion* lines the chorion concentrically. It is filled with a serous fluid, and contains the fœtus. In the first days of fœtal existence, it is thin, transparent, easily lacerable, and somewhat resembling the retina. At first, it adheres to the chorion only by a point, which corresponds to the abdomen of the fœtus; the other portions of the membranes being separated by the fluid already mentioned, called the *false liquor amnii*. Afterwards, the membranes coalesce, and adhere by very delicate cellular filaments; but the adhesion is feeble, except at the placenta and umbilical cord.

In the course of gestation, this membrane becomes thicker and tougher; and, at the full period, it is more tenacious than the chorion; elastic, semitransparent and of a whitish colour.

Like the chorion, it covers the fœtal surface of the placenta, envelopes the umbilical cord, passes to the umbilicus of the fœtus, and commingles there with the skin.

It has been a question, whether the amnion is supplied with blood-vessels. Velpeau denies it: Haller and others have maintained the affirmative. Haller asserts, that he saw a branch of the umbilical artery creeping upon it. The fact of the existence of a fluid within it, which is presumed to be secreted by it, would also greatly favour the affirmative. But, admitting that it is supplied with blood-vessels, a difference has existed, with regard to the source whence they proceed; and anatomical investigation has not succeeded in dispelling it. Monro affirms, that on injecting warm water into the umbilical arteries of the fœtus, the water oozed from the surface of the

amnion. Wrisberg asserts, that he noticed the injection to stop between the chorion and amnion; and Chaussier obtained the same results as Monro, by injecting the vessels of the mother.

The amnion contains a serous fluid, the quantity of which is in an inverse ratio to the size of the new being; so that its weight may be several drachms, when that of the fœtus is only a few grains. At first, the *liquor amnii*,—for so it is called,—is transparent; but, at the full period, it has a milky appearance, owing to flocculi of an albuminous substance held in suspension by it. It has a saline taste, a spermatic smell, and is viscid and glutinous to the touch. Vauquelin and Buniva found it to contain, water, 98.8; albumen, muriate of soda, soda, phosphate of lime, and lime, 1.2. That of the cow, according to these gentlemen, contains amniotic acid; but Prout, Dulong, and Labillardiére and Lassaigne were not able to detect it. Prout found some sugar of milk in the liquor amnii of the human female; Berzelius detected fluoric acid in it; Scheele, free oxygen; and Lassaigne, in one experiment, a gas resembling atmospheric air; in others, a gas composed of carbonic acid and azote. The chymical history of this substance is, consequently, sufficiently uncertain, nor is its formation placed upon surer grounds;—some physiologists ascribing it to the mother, others to the fœtus;—opinions fluctuating, according to the presumed source of the vessels, that supply the amnion with arterial blood. It has even been supposed to be the transpiration of the fœtus, or its urine. One reply to these views is, that we find it in greater relative proportion when the fœtus is small. Meckel thinks, that it proceeds chiefly from the mother, but that, about the termination of pregnancy, it is furnished in part by the fœtus. The functions, however, to which, as we shall see, it is probably inservient, would almost constrain us to consider it a secretion from the maternal vessels. It is interesting, also, to recollect, that, in the experiments of Dr. Blundell, which consisted in obliterating the vulvo-uterine canal in rabbits; and, when they had recovered from the effects of the injury, putting them to the male,—although impregnation did not take place, the wombs—as in extra-uterine pregnancy—were evolved, and the waters collected in the uterus. The fluid, consequently, must, in these cases, have been secreted from the interior of the uterus. May not the liquor amnii be secreted, in this manner, throughout the whole of gestation, and pass through the membranes of the ovum by simple imbibition? and may not the fluid secretions of the fœtus, which are discharged into the liquor amnii, pass through the membranes, and enter the system of the mother, in the same way?

The quantity of the liquor amnii varies in different individuals, and in the same individual, at different pregnancies, from four ounces to as many pints. Occasionally, it exists to such an amount as even to throw obscurity over the very fact of pregnancy. An instance of this kind, strongly elucidating the necessity of the most careful attention on the part of the practitioner in such cases, occurred in the

practice of a respectable London practitioner,—a friend of the author. The abdomen of a lady had been for some time enlarging by what was supposed to be abdominal dropsy: fluctuation was evident, yet the case appeared to be equivocal. A distinguished accoucheur, with a surgeon of the highest eminence, were called in consultation, and after examination, the latter declared, that "it was an Augean stable, which nothing but the trocar could clear out." As the lady, however, was even then complaining of intermittent pain, it was deemed advisable to make an examination *per vaginam*. The os uteri was found dilated and dilating, and in a few hours after this formidable decision, she was delivered of a healthy child, the gush of liquor amnii being enormous. After its discharge the lady was reduced to the natural size, and the *dropsy*, of course, disappeared!

3. The *cortical membrane* or *cortex ovi* is, according to Boër and Granville, the one, which is usually regarded as a uterine production, and denominated the *decidua reflexa*. It surrounds the ovule when it descends into the uterus, and envelopes the shaggy chorion. This membrane is destined to be absorbed during the first months of utero-gestation, so as to expose the next membrane to the contact of the decidua, with which a connexion takes place in the part where the placenta is to be formed. In that part, Boër and Granville consider, that the cortex ovi is never altogether obliterated, but only made thinner; and in process of time it is converted into a mere pellicle or envelope, which not only serves to divide the filiform vessels of the chorion into groups or cotyledons, in order to form the placenta, but also covers those cotyledons. This, Dr. Granville calls the *membrana propria*.

4. *Placenta*. This is a soft, spongy, vascular body, formed at the surface of the chorion, adherent to the uterus, and connected with the fœtus by the umbilical cord. The placenta is not in existence during the first days of the embryo state; but its formation commences, perhaps, with the arrival of the embryo in the uterus. In the opinion of some, the flocculi, which are at first spread uniformly over the whole external surface of the chorion, gradually congregate from all parts of the surface into one, uniting with vessels, proceeding from the uterus, and traversing the decidua, to form the placenta;—the decidua disappearing from the uterine surface of the placenta about the middle of pregnancy, so that the latter comes into immediate contact with the uterus. In the opinion of others, the placenta is formed by the separation of the layers of the chorion, and by the developement of the different vessels, that creep between them. Again, Velpeau maintains, that the placenta forms only at the part of the ovule, which is not covered by the true decidua, and which is immediately in contact with the uterus; and that it results from the developement of the granulations that cover this part of the chorion; these granulations or villi, according to Velpeau,

being gangliform organs containing the rudiments of the placental vessels.

The mode, in which the placenta is attached to the uterus, has always been an interesting question with physiologists; and it has been revived, of late, by Messrs. Lee, Radford, and others. The common opinion has been, that the large venous canals of the uterus are uninterruptedly continuous with those of the placenta. Wharton and Reuss, and a number of others, conceive that, at an early period of pregnancy, the part of the uterus, in contact with the ovum, becomes fungous or spongy, and that the *fungosities*, which constitute the uterine placenta, commingle and unite with those of the chorion so intimately, that laceration necessarily occurs when the placenta is extruded; and Dubois goes so far as to consider the milk-fever as a true traumatic disease, produced by such rupture! The opinion of Messrs. Lee, Radford, Velpeau and others is, that the maternal vessels do not terminate in the placenta; but that apertures—portions scooped out, as it were,—exist in their parietes, which are closed up, according to the two first gentlemen, by the true decidua,—according to Velpeau, by a membranule or anorganic pellicle, which he conceives to be thrown out on the fungous surface of the placenta, or by some valvular arrangement, the nature of which has not been discovered; but these apertures have no connexion, in his opinion, with any vascular orifice, either in the membrane or the placenta.

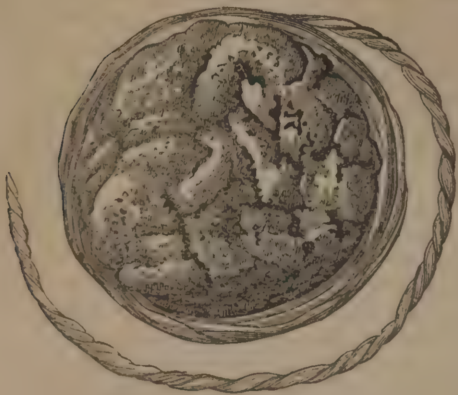
The mode, therefore, in which these authors consider the placenta to be attached to the uterus is, so far as it goes, somewhat unfavourable to the idea generally entertained, that the maternal vessels pour their flood into the maternal side of the placenta, whence it is taken up by the radicles of the umbilical vein. Whatever blood is exhaled must necessarily pass through the decidua, according to Lee and Radford; or through the pellicle, according to Velpeau. Biancini maintains, that a number of flexuous vessels connect the uterus directly with the placenta, which are developed immediately after the period of conception. These utero-placental vessels, he says, are not prolongations of the uterine vessels, but a new production.

This is an interesting, but unsettled, topic of anatomy, but one on which we are precluded from dwelling. In whatever manner originally produced, the placenta is distinguishable in the second month, at the termination of which, it covers two-thirds, or, at the least, one-half of the ovum; after this, it is observed to go on successively increasing. Prior to the full term, however, it is said to be less heavy, more dense, and less vascular, owing, it has been conceived, to several of the vessels, that formed it, having become obliterated and converted into hard, fibrous filaments; a change which has been regarded as a sign of maturity in the fœtus, and a prelude to its birth.

At the full period, its extent has been estimated at about one-fourth of that of the ovum; its diameter from six to eight inches:

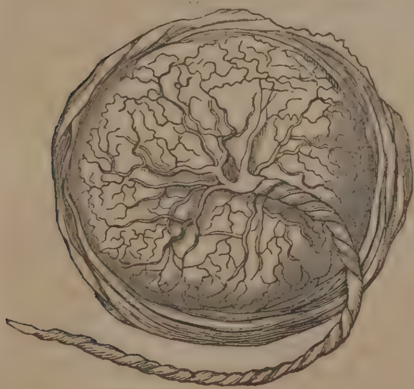
its circumference, twenty-four inches; its thickness from an inch to an inch and a quarter at the centre, but less than this at the circumference; and its weight, with the umbilical cord and membranes, from twelve to twenty ounces. All this is subject, however, to much variation. It is of a circular shape, and the cord is usually inserted into its centre. It may be attached to any part of the uterus, but is usually found towards the fundus. Of its two surfaces, that, which corresponds to the uterus, is divided into irregularly rounded lobes or *cotyledons*, and it is covered by a soft and delicate cellulo-vascular membrane, which, according to Chaussier,—who believes that the decidua invests the whole ovum,—is the decidua. Wrisberg, Lobstein, and Desormeaux, however, who consider that the decidua disappears from behind the placenta about the fourth or fifth month, regard it as a new membrane; whilst Velpeau maintains that the true decidua never exists there.

Fig. 173.



Uterine surface of the Placenta.

Fig. 173.



Fœtal surface of the Placenta.

The *fœtal or umbilical surface* is smooth, polished, covered by the chorion and amnion, and exhibits the distribution of the umbilical vessels, and the mode in which the cord is attached to the organ.

The following are the anatomical constituents of the placenta, as usually described by anatomists. *First.* Blood-vessels, from two sources,—the mother and the fœtus. The former proceed from the uterus, and consist of arteries and veins, of small size but considerable number. The vessels, which proceed from the fœtus, are those that constitute the umbilical cord;—viz. the umbilical vein, and the umbilical arteries. These vessels, after having penetrated the fœtal surface of the placenta, divide in the substance of the organ, so that each lobe has an arterial and a

venous branch, which ramify in it, but do not anastomose with the vessels of other lobes. *Secondly.* Expansions of the chorion, which are described by some as dividing into cellular sheaths and accompanying the vessels to their final ramifications;—an arrangement which is, however, contested by others. *Thirdly.* White filaments, which are numerous in proportion to the advancement of pregnancy, and which seem to be obliterated vessels. *Fourthly.* A kind of intermediate cellular tissue, serving to unite the vessels together, and which has been regarded, by some anatomists, as an extension of the decidua accompanying those vessels. *Lastly.* A quantity of blood poured into this intermediate cellular tissue, which may be removed by washing.

In addition to these constituents, a glandular structure has been presumed to exist in it; as well as lymphatic vessels. Fohmann affirms, that the umbilical cord, in addition to the blood-vessels, consists solely of a plexus of absorbent vessels, which may be readily injected with mercury. This has been done also by Dr. Montgomery, of Dublin. These lymphatics of the cord communicate with a net-work of lymphatics, seated between the placenta and the amnion, the termination of which Fohmann could not detect, but he thinks they pass to the uterine surface of the placenta. These vessels proceed to the umbilicus of the child, and chiefly unite with the subcutaneous lymphatics of the abdominal parietes; follow the superficial veins; pass under the crural arches; ramify on the iliac gland; and terminate in the thoracic duct. Chaussier and Ribes describe nerves in the placenta proceeding from the great sympathetic of the fœtus.

The uterine and the fœtal portions of the placenta are generally described as quite distinct from each other, during the two first months of fœtal life; but afterwards they constitute one mass. Still, the uterine vessels remain distinct from the fœtal; the uterine arteries and veins communicating freely with each other, as well as the fœtal arteries and veins; but no direct communication existing between the maternal and fœtal vessels. Until of late, almost every obstetrical anatomist adopted the division of the placenta into two parts, constituting—as it were—two distinct placentæ,—the one maternal, the other fœtal. Messrs. Lee, Radford, Millard, Biancini and others have, however, contested this point, and have affirmed, with Velpeau, that the human placenta is entirely fœtal. The very fact, indeed, of the existence of a membrane, or—as M. Velpeau calls it—a 'membranule,' between the placenta and the uterus, destroys the idea of any direct adhesion between the placenta and uterus, and makes the placenta wholly fœtal. Yet the point is still contested, by those especially, who consider that the maternal vessels ramify on one surface of the placenta, and the fœtal on the other.

5. *Umbilical cord.*—From the fœtal surface of the placenta a cord of vessels passes, which enters the umbilicus of the fœtus, and

has hence received the name *umbilical cord*, as well as that of *navel-string*. It forms the medium of communication between the fœtus and the placenta.

During the first month—Pockels says the first three weeks—of fœtal existence, the cord is not perceptible; the embryo appearing to be in contact, by the anterior part of its body, with the membranes of the ovum. Such, at least, is the description of most anatomists; but Velpeau says it is erroneous. The youngest embryo he dissected had a cord. At a fortnight and three weeks old, the dimension is three or four lines; and, he thinks, his examinations lead him to infer, that, at every period of fœtal developement, the length of the cord is nearly equal to that of the body, if it does not exceed it a little.

In an embryo, a month old, Béclard observed vessels creeping, for a certain space, between the membranes of the ovum, from the abdomen of the fœtus to a part of the chorion, where the rudiments of the future placenta were visible. During the fifth week, the cord is straight, short, and very large, owing to its containing a portion of the intestinal canal. It presents, also, three or four dilatations, separated by as many contracted portions or necks; but these gradually disappear; the cord lengthens, and becomes smaller, and occasionally it is twisted, knotted and tuberculated in a strangely inexplicable manner, (Fig. 174.) After the fifth week, it contains—besides the duct of the umbilical vesicle—the omphalo-mesenteric vessels, and a portion of the urachus, or of the allantoid, and of the intestines. At about two months, the digestive canal enters the abdomen: the urachus, the vitelline canal—to be mentioned presently—and the vessels become obliterated, so that, at three months, as at the full period, the umbilical cord is composed of three vessels,—the umbilical vein, and two arteries of the same name,—of a peculiar jelly-like substance, and it is surrounded, as we have seen, by the amnion and chorion. The vessels will be more particularly described hereafter. They are united by a cellular tissue, containing the *jelly of the cord*, or *of Wharton*, a thick albuminous secretion, which bears some resemblance to jelly, and the quantity of which is very variable. In the fœtus, the cellular tissue is continuous with the sub-peritoneal cel-

Fig. 174.

Umbilical cord.

lular tissue; and in the placenta, it is considered to accompany the ramifications of the vessels.

It has been already remarked, that Chaussier and Ribes have traced branches of the great sympathetic of the fœtus as far as the placenta; and the same has been done by Durr, Rieck and others.

6. *Umbilical vesicle.*—This vesicle, called also *intestinal vesicle*, appears to have been first carefully observed by Albinus. Dr. Granville, however, ascribes its discovery to Bojanus. It was unknown to the ancients; and, amongst the moderns, is not universally admitted to be a physiological condition. Osiander and Döllinger class it amongst imaginary organs; and Velpeau remarks, that out of about two hundred vesicles, which he had examined, in fœtuses under three months of developement, he had met with only thirty in which the umbilical vesicle was in a state, that could be called natural. Under such circumstances, it is not easy to understand how he could distinguish the physiological from the pathological condition. If the existence of the vesicle be a part of the physiological or natural process, the majority of vesicles ought to be healthy or natural: yet he pronounces the thirty in the two hundred to be alone properly formed; and, of consequence, one hundred and seventy to be morbid or unnatural.

This vesicle is described as a small, pyriform, round or spheroidal sac; which, about the fifteenth or twentieth day after fecundation, is of the size of a common pea. It probably acquires its greatest dimensions in the course of the third or fourth week. After a month, Velpeau always found it smaller. About the fifth, sixth or seventh week it is of about the size of a coriander seed. After this it becomes shriveled and disappears insensibly. It seems to be situated between the chorion and amnion, and is commonly adherent either to the outer surface of the amnion, or to the inner surface of the chorion, but, at times, it is situated loosely between them.

The characters of the *vitelline pedicle*, as Velpeau terms it, which attaches the vesicle to the embryo, vary according to the stage of gestation. At the end of the first month, it is not less than two, nor more than six lines long, and about a quarter of a line broad. Where it joins the vesicle, it experiences an infundibuliform expansion.

Its continuity with the intestinal canal appears to be undoubted. Up to twenty or thirty days of embryonic life, the pedicle is hollow, and, in two subjects, M. Velpeau was able to press the contained fluid from the vesicle into the abdomen, without lacerating any part. Generally, the canal does not exist longer than the expiration of the fifth week, and the obliteration appears to proceed from the umbilicus towards the vesicle.

The parietes of the *vitelline pouch*—as M. Velpeau also calls it, from its analogy to the vitelline or yolk-bag of the chick—are strong and resisting; somewhat thick, and difficult to tear.

As the umbilical vesicle of brutes has been admitted to be continuous with the intestinal canal, anatomists have assigned it and its pedicle three coats. Such is the view of Dutrochet. Velpeau has not been able to detect these in the human fœtus. He admits, however, a serous surface, and a mucous surface.

The vesicle is evidently supplied with arteries and veins, which are generally termed *omphalo-mesenteric*, but, by Velpeau, *vitello-mesenteric*, or, simply, *vitelline*. The common belief is, that they communicate with the superior mesenteric artery and vein; but Velpeau says he has remarked, that they inosculate with one of the branches of the second or third order of those great vessels (*canaux*); with those, in particular, that are distributed to the cæcum. These vessels he considers to be the vessels of nutrition of the umbilical vesicle.

The fluid, contained in the vesicle, which Velpeau terms the *vitelline* fluid, has been compared, from analogy, to the *vitellus* or yolk of birds. In a favourable case for examination, Velpeau found it of a pale yellow colour; opaque; of the consistence of a thickish emulsion; different in every respect from serosity, to which Albinus, Boerhaave, Wrisberg and Lobstein compared it, and from every other fluid in the organism; and he regards it as a nutritive substance—a sort of oil—in a great measure resembling that, which constitutes the vitelline fluid of the chick *in ovo*.

7. *Allantoid vesicle* or *allantois*.—This vesicle—called also *membrana farciminalis* and *membrana intestinalis*—has been alternately admitted and denied to be a part of the appendages of the human fœtus, from the earliest periods until the present day. It has been seen by Emmert, Meckel, Pockels, Velpeau, Von Baer, Burdach and others. It is situated between the chorion and amnion, and communicates, in animals, with the urinary bladder by a duct called *urachus*. It has been observed in the dog, sheep, cow, in the saurian and ophidian reptiles, birds, &c. M. Velpeau was never able to detect any communication with the bladder in the human subject, and he is compelled to have recourse to analogy to infer, that any such channel has, in reality, existed. From all his facts—which are not numerous or forcible—he 'thinks himself authorized to say,' that, from the fifth week after conception till the end of pregnancy, the chorion and amnion are separated by a transparent, colourless, or slightly greenish-yellow layer. This layer, instead of being a simple serosity, is lamellated, after the manner of the vitreous humour of the eye. It diminishes in thickness, in proportion to the developement of the other membranes. The quantity of fluid, which its meshes inclose, is, on the contrary, in an inverse ratio with the progress of gestation. Becoming gradually thinner, it is ultimately formed into a homageneous and pulpy layer, by becoming transformed into a simple gelatinous or mucous layer (*enduit*), which wholly disappears, in many cases, before the period of accouchement.

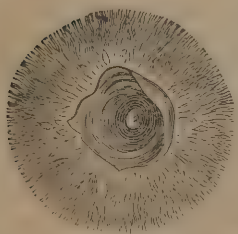
Between the *reticulated body*, as Velpeau terms it, and the allantoid of oviparous animals, he thinks, there is the greatest analogy. Yet the fluid of the allantoid is very different from the urine, which is supposed, by some, to exist in the allantoid of animals. This fluid, we shall find, has been considered inservient to the nutrition of the new being, but, after all, it must be admitted, that our ideas regarding the vesicle, in man, are far from being determinate.

8. *Erythroid vesicle.*—This vesicle was first described by Dr. Pockels, of Brunswick, as existing in the human subject. It had been before observed in the mammalia. According to Pockels, it is pyriform; and much longer than, though of the same breadth as, the umbilical vesicle. Within it, the intestines are formed. Velpeau, however, asserts, that he has never been able to meet with it; and he is disposed to think, that none of the embryos, depicted by Pockels, and by Mr. Seiler, were in the natural state.

According to most obstetrical physiologists, when pregnancy is multiple, the ova in the uterus are generally distinct, but contiguous to each other. By others, it has been affirmed, that two or more children may be contained in the same ovum, but this appears to require confirmation. The placenta of each child, in such multiple cases, may be distinct; or the different placentæ may be united into one, having intimate vascular communications with each other. At other times, in twin cases, but one placenta exists. This gives origin to two cords, and at others to one only, which afterwards bifurcates, and proceeds to both fœtuses. Maygrier, however, affirms unconditionally, that there is always a placenta for each fœtus; but that it is not uncommon, in double pregnancies, to find the two placentæ united at their margins; the circulation, however, of each fœtus being distinct, although the vessels may anastomose.

II. *OF THE FŒTUS.*—The ovule does not reach the uterus until towards the termination of a week after conception. On the seventh or eighth day, it has the appearance referred to in the case so often cited from Sir Everard Home; the future situations of the brain and spinal marrow being recognizable with the aid of a powerful microscope. On the thirteenth or fourteenth day, according to Maygrier, the ovum is perceptible in the uterus, and of about the size of a pea, containing a turbid fluid, in the midst of which an opaque point is suspended, the *punctum saliens.* Its weight has been valued at about a grain.

Fig. 175.

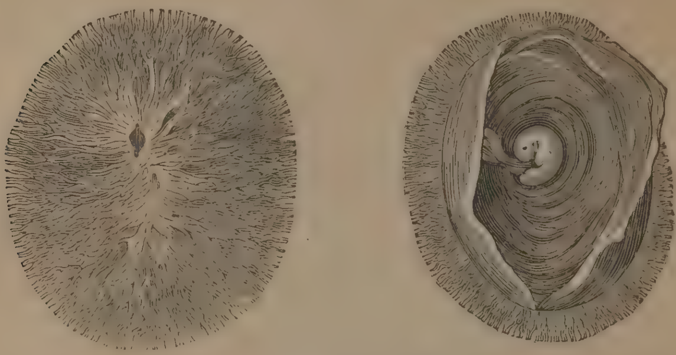


Ovum and embryo, fifteen days old.

On the twenty-first day, the embryo appears under the shape of a large ant, according to Aristotle; of a grain of lettuce; of a grain of barley, according to Burton; or of the malleus of the ear, according to Baudelocque. At this period, the different parts of the embryo have a little more consistence; and

those that have afterwards to form bone, assume the cartilaginous condition. On the thirtieth day, some feeble signs of the principal organs and of the situation of the upper limbs are visible;—length four or five lines.

Fig. 176.



Ovum and embryo, twenty-one days old.

About the forty-fifth day, the shape of the child is determinate; and it now, in the language of some anatomists, ceases to be the *embryo*, and becomes the *fœtus*.

Fig. 177.

Fœtus at forty-five days.

The limbs resemble tubercles, or the shoots of vegetables; the body lengthens, but preserves its oval shape, the head bearing a considerable proportion to the rest of the body. The base of the trunk is pointed and elongated. Blackish points, or lines, indicate the presence of the eyes, mouth, and nose; and similar, parallel points correspond to the situation of the vertebræ. Length ten lines.

In the second month, most of the parts of the fœtus exist. The black points, which represented the eyes, enlarge in every dimension; the eyelids are sketched, and are extremely transparent; the nose begins to stand out; the mouth increases, and becomes open; the brain is soft and pulpy; the heart is largely developed, and opaque lines set out from it; which are the first traces of large vessels. The fingers and toes are distinct.

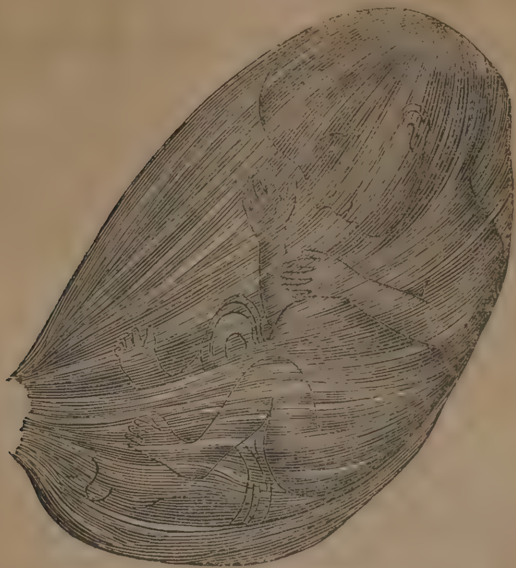
Fig. 178.

Fœtus at two months.

In the third month, the eyelids are more developed, and firmly closed. A small hole is perceptible in the pavilion of the ear. The alæ nasi are distinguishable. The lips are very distinct, and approximated, so that the mouth is closed. The genital organs of both sexes undergo an extraordinary increase during this month. The penis is very long; the scrotum empty, frequently contain-

ing a little water. The vulva is very apparent, and the clitoris prominent. The brain, although still pulpy, is considerably developed, as well as the spinal marrow. The heart beats forcibly. The lungs are insignificant; the liver very large, but soft and pulpy, and appears to secrete scarcely any bile. The upper and lower limbs are developed. Weight two and a half ounces: length three and a half inches.

Fig. 179.



Fœtus at three months, in its membranes.

During the fourth month, all the parts acquire great developement and character, except perhaps the head and the liver, which increase less in proportion than the other parts. The brain and spinal marrow acquire greater consistence: the muscular system, which began to be observable in the preceding month, is now distinct; and slight, almost imperceptible, movements begin to manifest themselves. The length of the fœtus is, at the end of one hundred and twenty days, five or six inches; the weight four or five ounces.

During the fifth month, the developement of every part goes on; but a distinction is manifest amongst them. The muscular system is well-marked, and the movements of the fœtus unequivocal. The head is still very large, compared with the rest of the body, and is covered with small, silvery hairs. The eyelids are glued together. Length seven to nine inches; weight six or eight ounces. If the fœtus be born at the end of five months, it may live for a few minutes.

In the sixth month the dermis begins to be distinguished from the epidermis. The skin is delicate, smooth, and of a purple colour; especially on the face, lips, ears, palms of the hands and soles of the feet. It seems plaited, owing to the absence of fat in the subcutaneous cellular tissue. The scrotum is small, and of a vivid red hue. The vulva is prominent, and its lips are separated by the projection of the clitoris. The nails appear, and, towards the termination of the month, are somewhat solid. Should the fœtus be born now, it is sufficiently developed to breathe and cry, but it dies in a few hours. Length, at six months, ten or twelve inches. Weight under two pounds.

During the seventh month, all the parts are better proportioned. The head is directed towards the orifice of the uterus, and can be felt by the finger introduced into the vagina, but it is still very movable. The eyelids begin to separate, and the membrane, which previously closed the pupil—the *membrana pupillaris*—to disappear. The fat is more abundant, so that the form is more rotund. The skin is redder, and its sebaceous follicles are formed, which secrete a white, sebaceous substance that covers it; and the testicles are in progress to the scrotum. The length at seven months is fourteen inches; the weight under three pounds.

In the eighth month, the fœtus increases proportionably more in breadth than in length. All its parts are firmer and more formed. The nails exist; and the child is now certainly *viable*, or capable of supporting an independent existence. The testicles descend into the scrotum; the bones of the skull, ribs, and limbs are more or less completely ossified. The length is sixteen inches; the weight four pounds and upwards.

At the full period of nine months, the organs have acquired the developement necessary for the continued existence of the infant. Length eighteen or twenty inches; weight six or seven pounds. Dr. Dewees says the result of his experience, in this country, makes the average weight above seven pounds.

The whole of this description amounts to no more than an approximation to the truth. The facts will be found to vary greatly in individual cases, and according to individual experience: and this accounts for the great discordance in the statements of different observers. This discordance is strongly exemplified in the following table, containing the estimates of the length and weight of the fœtus at different periods of intra-uterine existence; as deduced by Dr. Beck from various observers, and as given by Maygrier on his own authority. It is proper to remark, that the Paris pound, *poids de marc*, of sixteen ounces, contains 9216 Paris grains, whilst the avoirdupois contains only 8532.5 Paris grains; and that the Paris inch is 1.065977 English inch.

	Length.		Weight.	
	Beck.	Maygrier.	Beck.	Maygrier.
At 30 days,	3 to 5 lines	10 to 12 lines	- -	9 or 10 grains
2 months,	2 inches	4 inches	2 ounces	5 drachms
3 do.	$3\frac{1}{2}$ do.	6 do.	2 to 3 ounces	$2\frac{1}{2}$ ounces
4 do.	5 to 6 do.	8 do.	4 or 5 do.	7 or 8 do.
5 do.	7 to 9	10 do.	9 or 10	16 ounces
6 do.	9 to 12	12 do.	1 to 2 pounds	2 pounds
7 do.	12 to 14	14 do.	2 to 3 do.	3 do.
8 do.	16	16 do.	3 to 4 do.	4 do.

The difficulty must necessarily be great in making any accurate estimate during the early periods of fœtal existence; and the changes in the after months are liable to considerable fluctuation. Chaussier affirms, that after the fifth month, the fœtus increases an inch every fifteen days, and Maygrier adopts his estimate. The former gentleman has published a table of the dimensions of the fœtus at the full period, deduced from an examination of more than fifteen thousand cases. From these we are aided in forming a judgment of the probable age of a fœtus in the latter months of utero-gestation;—a point of interest with the medico-legal inquirer. At the full period, the middle of the body corresponds exactly with the umbilicus; at eight months, it is three-quarters of an inch, or an inch higher. At seven months it approaches still nearer the sternum; and at six months it falls exactly at the lower extremity of that bone; hence, if we depend upon these admeasurements, should the middle of the body of the fœtus be found to fall at the lower extremity of the sternum, we may be justified in concluding that the fœtus is under the seventh month, and consequently not *viable* or rearable. A striking circumstance, connected with the developement of the fœtus, is the progressive diminution in the proportion between the part of the body above the umbilicus and that below it. At a very early period of fœtal life, (see Figs. 177, and 178,) the cord is attached near the base of the trunk; but the parts beneath become gradually developed, until its insertion ultimately falls about the middle of the body.

The following table of the length and weight (French), and central point of the fœtus at different ages is given by M. Lepelletier. It still farther exhibits the discordance to which we have alluded above.

Month.	Length.	Weight.	Central point.
1	5 or 6 lines	9 to 15 grains	at the junction of the head and trunk.
2	18 to 20 lines	6 to 8 drachms	at the upper part of the sternum.
3	2 to 3 inches	2 or 3 ounces	at the upper extremity of the xiphoid cartilage.
4	5 to 6 inches	10 to 16 ounces	at the middle of the xiphoid cartilage.
5	7 to 9 inches	1 to 2 pounds	at the lower extremity of the xiphoid cartilage.
6	9 to 12 inches	2 to 3 pounds	several lines below the xiphoid cartilage.
7	12 to 15 inches	3 to 4 pounds	equidistant between the cartilage and the umbilicus.
8	15 to 18 inches	4 to 6 pounds	an inch above the umbilicus.
9	16 to 20 inches	6 to 8 pounds	at the umbilicus.
	Extremes, 12 to 15 inches (Millot.)	*Extremes,* 2 to 16 pounds (Voistel.)	

The position of the fœtus in utero, and the cause of such position at various periods of utero-gestation, have been topics of some interest. In the early weeks, it seems to be merely suspended by the cord; and it has been conceived, that because the head is heavier, it is the lowest part. It is difficult, however, to admit this as the cause of the position assumed in such an immense majority of cases, or to fancy, that the nice adaptation of the fœtal position to the parts through which the child has to pass is simply dependent upon such a mechanical cause. Gravity can afford us no explanation why the face, in 12,120 cases out of 12,633, has been found turned to the right sacro-iliac synchondrosis, (see Fig. 160,) and the occiput to the left acetabulum; and in the 63 of these cases in which the face was turned forwards, and in the 198 breech presentations, are we to presume, that the whole effect was owing to mere difference of weight in those parts that were lowest?

The common position of the fœtus, at the full period, is exhibited in the above illustration. The body is bent forward, the chin resting on the chest, the occiput towards the brim of the pelvis, the arms approximated in front, and one or both lying upon the face; the thighs bent upon the abdomen, the knees separated, the legs crossed, and drawn up, and the feet bent upon the anterior surface of the leg; so that the oval, which it thus forms, has been estimated at about ten inches in the long diameter; the head, at the full period, resting on the neck, and even on the mouth, of the womb, and the breech corresponding to the fundus of the organ.

Fig. 180.

Full period of utero-gestation.

From the first moment of a fecundating copulation, the minute matters, furnished by both sexes, when commingled, commence the work of forming the embryo. For a short time, they find in the ovum the necessary nutriment, and subsequently obtain it from the uterus. The mode, in which this action of formation is accomplished, is as mysterious as the essence of generation itself. When the impregnated ovum is first seen, it seems to be an amorphous, gelatinous mass, in which no distinct organs are perceptible. In a short time, however, the brain and spinal marrow, and blood-vessels, make their appearance, but which of these is first developed is undecided.

Sir Everard Home,—from his observations of the chick in ovo, as well as from the microscopic appearances, presented by the ovum in the case of the female who died on the seventh or eighth day after impregnaton, in which a rudimental brain and spinal marrow

were perceptible,—decides, that the parts, first formed, bear a resemblance to brain, and that the heart and arteries are produced in consequence of the brain having been established. Prévost and Dumas, Velpeau, and Rolando also assign the priority to the nervous system. Meckel, however, admits no primitive organizing element, but believes, that the first rudiments of the fœtus contain the basis of every part. On the other hand, the recent researches of Serres, on the mode of developement of the nervous system, have induced him to be in favour of the earlier appearance of the blood-vessels; and this view appears to be supported by the fact, that if an artery of the brain is wanting or is double, the nervous part to which it is usually distributed is also wanting or double. The acephalous fœtus has no carotid or vertebral arteries; whilst the bicephalous or tricephalous have those vessels double or treble. With these views, Dr. Granville accords, and he lays it down as a law, that the nerves invariably appear after the arteries which they are intended to accompany.

A like discordance exists in the views regarding the precedence in formation of the blood-vessels. The blood is clearly formed before the heart. It appears at two distinct points from it, and acquires a motion independently of it. The veins are formed first; the heart next, and lastly the arteries. This is the view of the generality of physiologists, but a distinguished Italian physiologist—Rolando—assigns the precedency to the arteries. Farther experiments are demanded on these interesting, but intricate, points of organogenia.

Messrs. Geoffroi Saint-Hilaire, Meckel, Serres, Tiedemann and others are of opinion, that the developement of the embryo takes place from the sides towards the median line—from the circumference towards the centre; but Velpeau considers that the median line is first formed. The spinal marrow is the first portion of the nervous system which appears; and this system, as we have seen, he thinks, precedes every other.

The successive developement of the different organs is a topic of deep interest to the student of general anatomy, and has engaged the attention of some of the most excellent anatomists of modern times. Amongst these, Rolando, Tiedemann, Ackermann, Serres, Velpeau, Walther, Béclard, Rosenmüller, Geoffroi Saint-Hilaire, and Meckel, are especially conspicuous. The nature and limits of this work will preclude us from entering into this investigation any farther than to point out some of the most striking peculiarities of fœtal life.

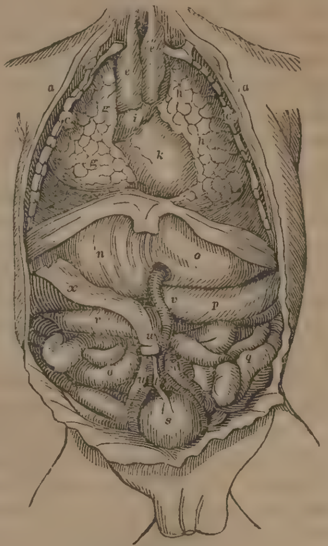
The head of the fœtus is large in proportion to the rest of the body, and the bones of the skull are united by membrane; the sagittal suture extends down to the nose, so as to divide the frontal bone into two portions; and, where this suture unites with the coronal, a quadrangular space is left, filled up by membrane, which is called the *anterior fontanelle* or *bregma*. Where the posterior extremity of the sagittal suture joins the lamboidal, a triangular space of a similar kind is left, called the *posterior fontanelle* or *posterior*

bregma. It is important for the obstetrical practitioner to bear in mind the shape of these spaces, as they indicate to him whether the anterior or posterior part of the head is the presenting part.

The pupil of the eye, in a very young fœtus, is entirely closed by a membrane, called *membrana pupillaris*, which arises from the inner margin of the iris, and continues there till the seventh month, when it gradually vanishes by absorption. It is a vascular substance, and, like the iris, to which it is attached, separates the two chambers of the eye from each other. Wachendorff first described it in 1738; and both he and Wrisberg detected vessels in it. Its vascularity was denied by Bichat, but it has been satisfactorily demonstrated by J. Cloquet. The membrane is manifestly connected with the process of formation of the delicate organ to which it is attached; and, according to Blumenbach, it keeps the iris expanded, during the rapid increase of the eyèball.

In the upper part of the thorax of the fœtus, a large gland, or rather glandiform ganglion exists, called the *thymus*. It is situated in the superior mediastinum, and lies over the top of the pericardium and the arch of the aorta. It has two long cornua above, and two broad lobes below. Its appearance is glandular, and colour very variable. In the progress of age it diminishes, so that in the adult it is wasted, and in old age can scarcely be discovered amongst the cellular tissue. It is surrounded by a thin, cellular capsule, which sends prolongations into its interior, and divides it into lobules of unequal size, on which several vesicles are distinguishable, filled with a milky fluid.

Fig. 181.



Fœtus at full term.

a, a. Divided integuments.—*c, c.* Divided ribs and intercostal muscles.—*e, e.* Lobes of thymus gland.—*g, g, h, h.* Lungs.—*i.* Right auricle of the heart.—*k.* Right ventricle.—*n, o.* Right and left lobes of the liver.—*p.* Stomach. *q, q.* Small intestines.—*r.* The colon.—*s.* Bladder of urine inflated.—*t.* The urachus.—*u, u.* The umbilical arteries.—*v.* The umbilical vein.—*w.* The umbilicus.—*x.* The collapsed umbilical cord.

The thymic arteries proceed from the inferior thyroid, internal mammary, bronchic, mediastinal, &c. The nerves proceed from the pneumogastric, diaphragmatic, and inferior cervical ganglia. It has no excretory duct; and is one of the most obscure, in its physiology, of any of the organs of the body.

The *thyroid gland*, which has been described in another place, and whose functions are equally obscure, is also largely developed in the fœtus; as well as the *supra-renal capsules.*

The *lungs*, not having received air in respiration, are collapsed

and dense, containing no more blood than is necessary for their nutrition. They are of a dark colour, like liver, and do not fill the cavities of the chest. Their specific gravity is greater than that of water, and consequently they sink in that fluid. On cutting into them, no air is emitted, and no hemorrhage follows. The *absolute* weight, however, of the lungs is less; no more blood, as we have seen, being sent to them than what is necessary for their nutriment; whilst, after respiration is established, the whole of the blood passes through them; the vessels are consequently filled with blood, enlarged, and the organs themselves increased in absolute weight. Ploucquet asserts, from experiments, that the weight of the lungs of a full-grown fœtus, which never respired, is to that of the whole body, as 1 to 70; whilst in those, in which respiration has been established, it is as 1 to 35; the absolute weight being thus doubled. These numbers cannot, however, be considered to afford a satisfactory average; the exceptions being numerous, but all show that, as might be expected, the absolute weight is less, prior to the establishment of respiration. The subject is one of great interest, connected with infanticide, and has been treated in a competent manner by Dr. T. Beck in his *Elements of Medical Jurisprudence*,—decidedly, in our opinion, the best medico-legal work in existence.

It is, however, in the circulatory system of the fœtus, that we meet with the most striking peculiarities. The heart is proportionably larger and more conical than in the adult. The *valve of Eustachius* —at the left side of the mouth of the inferior vena cava, where this vessel joins the sinus venosus,—is larger than at an after period, and is supposed to direct the principal part of the blood of that cava directly through the opening which exists between the right and left auricle.

This opening, which is called the *foramen ovale* or *foramen of Botal*, is in the septum between the auricles, and is nearly equal in size to the mouth of the inferior cava. It is situated obliquely, and has a membrane, forming a distinct valve, and somewhat of a crescentic shape, which allows part of the blood of the right auricle to pass through the opening into the left auricle, but prevents its return.

Fig. 182.

Thoracic viscera of the fœtus.
A, A. Lungs.—B. Right auricle.—C. Left arricle.—D. Right ventricle.—E. Pulmonary artery.—F. Aorta.—*a*. Ductus arteriosus.

The pulmonary artery, instead of bifurcating as in the adult, divides into three branches;—the right and left going to the lungs of the corresponding side, whilst the middle branch,—to

which the name *ductus arteriosus* has been given,—opens directly into the aorta; so that a great part of the blood of the pulmonary artery passes directly into that vessel. From the internal iliac arteries, two considerable vessels arise, called the *umbilical arteries.* These mount by the sides of the bladder, as in Fig. 181, on the outside of the peritoneum and perforate the umbilicus in their progress to the umbilical cord and placenta.

The *umbilical vein*, which is also a constituent of the cord, and conveys the blood from the placenta to the fœtus, arises from the substance of the placenta by a multitude of radicles, which unite together to form it. Its size is considerable. It enters the umbilicus, (Fig. 181); passes towards the inferior surface of the liver, and joins the left branch of the vena porta hepatica. Here a vessel arises called the *ductus venosus*, which opens into the vena cava inferior, or joins the left vena hepatica, where that vein enters the cava. A part only of the blood of the umbilical vein goes directly to the vena cava; the remainder is distributed to the right and left lobes of the liver, especially to the latter.

The digestive apparatus exhibits few peculiarities. The bowels, at the full period, always contain a quantity of greenish, or deep black, viscid fæces, to which the term *meconium* has been applied, owing to their resemblance to the inspissated juice of the poppy, (μηκων, 'a poppy.') It appears to be a compound of the secretions from the intestinal canal and bile, and frequently contains down or fine hairs mixed with it.

The liver is very large; so much so as to occupy both hypochondriac regions; and the right and left lobes are more nearly of a size than in the adult.

The urinary bladder is of an elongated shape, and extends almost to the umbilicus. The muscular coat is somewhat thicker and more irritable than in the adult, and it continues to possess more power during youth. The common trick of the school-boy—of sending the jet over his head—is generally impracticable in more advanced life.

From the fundus of the bladder, a ligament of a conical shape, called the *urachus*, (Fig. 181), ascends between the umbilical arteries to the umbilicus; becoming confounded in this place with the abdominal aponeuroses, according to Bichat, and forming a kind of suspensory ligament to the bladder. It is sometimes found hollow in the human fœtus, but such a formation Bichat considers to be preternatural. In the fœtal quadruped, it is a large canal, which transmits urine to the *allantois*, of which, as well as of other fœtal peculiarities, we have previously treated.

Lastly, the genital organs require some notice. The successive developement of this part of the system has given rise to some singular views regarding the cause of the sex of the fœtus. During the first few weeks, the organs are not perceptible; but, about the termination of the fifth week, a small, cleft eminence appears,

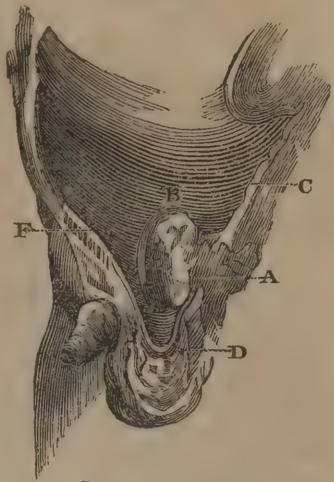
which is the rudiment of the scrotum or the vulva, according to the sex. In the sixth week, an aperture is perceptible, common to the anus and genital organs, in front of which is a projecting tubercle. In the seventh and eighth weeks, this tubercle seems to be tipped by a glans, and grooved beneath by a channel which extends to the anus. In the eleventh and twelfth weeks, the perineum is formed and separates the anus from the genital organs. In the fourteenth week, the sex is distinct; but there still remains, for some time, a groove beneath the clitoris or penis, which becomes closed in the former, and is made into a canal in the latter.

The striking similarity between the male and female organs has led Tiedemann to conclude, that the female sex is the male, arrested at an inferior point of organization. In his view, every embryo is originally female; the cleft, described above, being the vulva,—the tubercle, the clitoris; to constitute the male sex, the cleft is united so as to form a raphe, the labia majora are joined to form the scrotum, the nymphæ to form the urethra, and the clitoris is transformed into a penis. In support of this opinion, Tiedemann asserts, that the lowest species of animals are almost all females; and that all the young acephali and aborted fœtuses, which have been examined, are of that sex.

On the other hand, Ackermann and Autenrieth assert, that the sexes are originally neuter, and that the future sex is determined by accidental circumstances, during the first week of fœtal life; whilst Velpeau is disposed to believe, that they are all male: the infra-pubic prolongation existing in every embryo, although there may be neither labia majora nor scrotum. But admitting, that the embryo belongs to either the one or the other sex, or is neutral, we must still remain at a loss regarding the influences, that occasion the subsequent mutations; and it seems impossible not to admit, that although an apparent sexual identity may exist amongst different embryos, there must be an impulse seated somewhere, which gives occasion to the sex being ultimately male or female, as it causes the young being to resemble one or other parent in its outward form, or internal configuration; and if our means of observation were adequate to the purpose, a distribution of arteries or nerves might probably be detected, which could satisfactorily account, *ab initio*, for the resulting sex. In the absence of such positive data, Geoffroy St. Hilaire has suggested, that the difference of sex may be owing to the distribution of the two branches of the spermatic artery. If they continue in approximation, proceeding together,—the one to the testicle, the other to the epididymis, the individual is male; if they separate,—the one going to the ovary, the other to the cornua of the uterus,—the individual is female. The degree of predominance of the cerebro-spinal system, he thinks, determines the approximation or separation of the two arterial branches. This predominance being greater in the male, the spermatic arteries are more feeble and consequently in greater proximity; and conversely.

Leaving these phantasies of the generalizing anatomist on a subject on which we must, probably, ever remain in the dark, let us inquire into the phenomena of the *descent of the testes* in the fœtus. In the early months of fœtal life, the testicle is an abdominal viscus, being seated below the kidney. About the middle of the third month of utero-gestation, it is about two lines long, and is situated behind the peritoneum, which is reflected over its ventral surface.—At this time, a sheath of peritoneum may be observed, passing from the abdominal ring to the lower part of the testicle, and containing a ligament, called *gubernaculum testis*, which is considered to be formed of elastic cellular tissue, proceeding from the upper part of the scrotum, and from the part of the general aponeurosis of the thigh near the ring, and of some muscular fibres coming from the internal oblique and transversalis muscles.

Fig. 183.

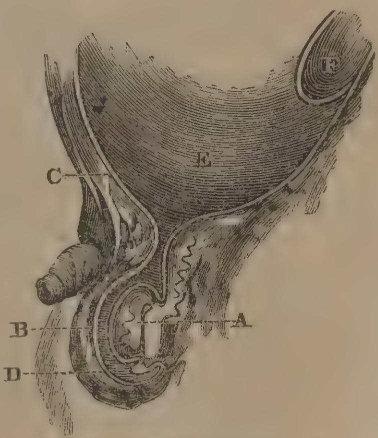


Descent of the testicle.

A. Testicle.—B. Peritoneal covering or tunica albuginea.—C. Peritoneum of the loins.—D. Peritoneum descending before the testicle.—F. Peritoneum lining the abdomen.

The head of the fœtus in utero being the lowest part, the testis has necessarily to ascend into the scrotum, and consequently some force must be exerted upon it. This is supposed to be effected by the contraction of the gubernaculum testis. About the seventh month the testes are in progress towards the scrotum. Fig. 183 exhibits one about to leave the abdomen and enter the scrotum, into which it generally passes about the eighth month. In this descent, the organ successively abandons one portion of the peritoneum to pass behind another immediately below, until the lowest part of the pouch, formed by the peritoneum, around the testicle, as in Fig. 184, becomes the tunica albuginea or first coat; whilst the portion of peritoneum, that descended before the testicle,

Fig. 184.



Descent of the testicle

A. Testicle in the scrotum.—B. Prolongation of the peritoneum.—C. Peritoneum lining the abdomen.—D. Peritoneum forming the tunica vaginalis.—E. Cavity of the peritoneum.—F. Kidney

becomes, when the testicle has fully descended, the second coat or tunica vaginalis.

As soon as the testicle has reached the lower part of the scrotum, the neck of the pouch approaches a closure, and this is commonly effected at birth. Sometimes, however, it remains open for a time, the intestines pass down, and congenital hernia is thus induced.

Physiology of the Fœtus.

In investigating this interesting point of human physiology, we shall inquire into the functions, in the order we have adopted respecting the functions of the adult. Over many of the topics, that will have to engage attention, the deepest obscurity rests; whilst the hypotheses, indulged regarding them, have been of the most fanciful and mystical character.

I. *Animal functions.*—The *external senses* in general are manifestly not in exercise during fœtal life: of this there can be no doubt, as regards the *sense of sight;* and the same thing probably applies to the *taste*, *smell*, and *hearing*. With regard to *tact*, however, we have the best reason for believing that it exists, particularly towards the latter periods of utero-gestation. The cold hand, applied over the abdomen of the mother, will instantly elicit the motions of the child. The brain and nervous system of the fœtus must, therefore, have undergone the developement, necessary for the reception of the impression made through the medium of the mother; to convey such impression to the percipient organ, and to accomplish perception.

The existence of most of the *internal sensations* or *wants* would of course be supererogatory in the fœtal state, where the functions, to which they excite after birth, are themselves wanting. It is probable that there is no digestion except of the mucous secretions of the tube; no excretion of fæces or urine, and certainly there is no pulmonary respiration. It is not unlikely, however, that internal impressions, originating in the very tissue of the organs, may be communicated to, and appreciated by, the brain. We have strong reason for believing that pain may be experienced by the fœtus; for if it be destroyed by any sudden influence in the latter periods of pregnancy, death will generally be preceded by irregular movements which are manifest to the mother, and frequently lead her to anticipate the result. Adelon asks, whether it may not be affected, under such circumstances, with convulsions, similar to those that animals experience when they die suddenly, especially from hemorrhage? It is impossible to reply to this question, but that the child suffers appears evident.

The most elevated of the functions of relation—the *mental* and *moral faculties*—would seem to be needless to the fœtus, and consequently little, if at all, exercised. Bichat and Adelon, considering that its existence is purely vegetative, are of opinion that they are

not exerted at all. Cabanis, however, suggests, that imperfect essays may, at this early period, be made by virtue of the same instinct, that impels animals to exercise their organs prior to the period at which they are able to derive service from them; as in the case of the bird, which will shake its wings before they are covered with feathers, and when yet incapable of bearing them.

It is difficult to deny to the fœtus *all* intellectual and moral manifestation. This must doubtless be obscurely rudimental; still, we may conceive that some may exist, if we admit that the brain is in a state for the perception of impressions, that tact is practicable, and instinct in full activity.

We find, moreover, that the power of *motion*, voluntary as well as involuntary, exists certainly after the fifth month, and probably much earlier, could it be appreciated. During the latter months of utero-gestation, the motion of the fœtus appears to be almost incessant, and can be distinctly felt by placing the hand upon the abdomen. At times, indeed, it is manifest to the sight. The cause of these movements is by no means clear. It is probable that they are instituted for the purpose of inducing a change in positions, which may have become irksome, and for assuming others; for we have already remarked, that the fœtus readily appreciates any sudden succussion given to it through the mother,—hence that it possesses tact, and, as we can readily understand, may experience fatigue from the maintenance of an inconvenient posture. This impression is conveyed to the brain, which sends out volition to the appropriate muscles, and the position is changed. All this proves, that the cerebral functions are exerted, but for a few definite objects only.

The function of *expression* is of course almost, if not entirely, null in the fœtus. There are cases upon record, where children are said to have cried in utero, so as to be heard distinctly, not only by the mother, but by those around her. Indeed, the objection, that an infant may respire before it is born, and yet not come into the world alive,—in which case there will be buoyancy and dilatation of the lungs,—has been seriously brought forward against the docimasia pulmonum or *lung-proof* of infanticide. We would not be understood to believe these cases to be mere fabrications, or the phenomenon impossible,—except, indeed, whilst the membranes are in a state of integrity. When they have given way, and the child's mouth presents towards the os uteri, breathing and the *vagitus* may be practicable, and may have occurred; but very positive and unexceptionable testimony is required to establish such an astounding event.

II. *Functions of Nutrition.*—These functions are not as numerous in the fœtus as they are in the adult. Their object is, however, the same;—the formation of the various parts of the organized machine, and their constant decomposition and renovation.

One of the least tenable hypotheses, that have been entertained, regarding the embryo at its first formation, is—that, for the first month—and why the period is thus limited is not apparent—the vi-

tality of the fœtus is not independent, but is a part, as it were an offset, of that of the mother; that it has no separate powers of existence; no faculty of self-evolution; and that its organs are nourished by the plastic materials, which it incessantly derives from the maternal blood. It appears manifest, that from the very moment of the union of the materials furnished by both sexes at a fecundating copulation, the elements of the new being must exist; and it must possess, within itself, the faculty of self-evolution; otherwise, how can we understand the phenomena that take place in the ovarium after fecundation? It is admitted that this last organ furnishes the unfecundated ovum, and that the sperm must come in contact with this ovum; after which, fecundation is accomplished, and immediately the ovum undergoes a farther developement; escapes, in due time, from the viscus in which it was formed; is laid hold of by the Fallopian tube; passes through that canal, and is deposited in the interior of the uterus, with which it ultimately contracts adhesions. But all this requires time. The ovum does not probably reach the uterus, in the human female, until about the end of a week; and some time must still elapse before such adhesions are effected; and, consequently, before anything like maternal blood, whence the plastic materials are derived, according to the view in question, could be sent to it. During the whole of this time, the embryo doubtless derives its nourishment from the albuminous matters with which it is surrounded in the ovum itself, in the same manner as the young of the oviparous animal obtains the nutriment necessary for its full developement during incubation, from the matters surrounding it; in which case the supply of fresh plastic materials, derived from the maternal blood, is obviously impossible. But, in due time, after it has attained the interior of the uterus, it is compelled to absorb appropriate nutriment from the mother; the minute quantity existing in the ovum, at this early period, being totally insufficient for the developement which the fœtus is destined to attain. In this last respect the human ovum differs from the eggs of oviparous birds, which are hatched out of the body, and contain sufficient nutriment for full fœtal evolution.

Since the time of Hippocrates, Aristotle, and Galen, different anatomists and physiologists have asserted, that the umbilical vein is the only channel through which nutriment reaches the fœtus, or, in other words, that the whole of the nourishment which the fœtus receives is from the placenta; but the facts, to which allusion has already been made, are sufficient to overturn this hypothesis. It is impossible that the placenta can have any agency until it is *in esse*. Such an explanation of the process of fœtal nutrition could only hold good after the first periods, and then, as we shall see, it is sufficiently doubtful. Accordingly, some of the most distinguished of modern physiologists, who have devoted their attention to embryology, have completely abandoned the idea of placental agency during the first months: and they, who have invoked it at all, have usually done so,

as regards the after periods only. On all this subject, however, we have the greatest diversity of views. Lobstein, for example, affirms, that the venous radicles of the rudimental placenta obtain nutritive fluids from the mother during the first days only, until the period when the arteries are formed; but that, after this, all circulation between the uterus and placenta ceases, and the fluid of the umbilical vesicle, the liquor amnii, and the jelly of the cord, are the materials of nutrition. Meckel thinks the placenta is never the source of nutritive materials. He regards it as an organ for the vivification of the blood of the fœtus, analogous to the organ of respiration in the adult; whilst nutrition is, in his opinion, accomplished by the matter of the umbilical vesicle in the beginning, by the liquor amnii until midterm, and by the jelly of the cord until the end. According to Béclard, nutrition is effected, during the first weeks, by the fluid of the umbilical vesicle; afterwards by the liquor amnii, and the jelly of the cord; and, as soon as the ovum becomes villous, and developes the placenta, by that organ. Adelon is of opinion, that two sources of nutrition ought alone to be admitted,—the umbilical vesicle, which is the sole agent for nearly two months, and the placenta for the remainder of the period. Lastly, M. Velpeau equally thinks, that the nutriment of the ovum is derived from different sources at different periods of intra-uterine existence. The embryo, he says, is at first but a vegetable, imbibing the surrounding humours. The villi of its circumference, which are true cellular *spongioles*, obtain nutritive principles in the Fallopian tube and in the uterus, to keep up the developement of the vesicles of the embryo; after which the new being is nourished like the chick in *ovo*, or rather like the plantule, which is, at first, altogether developed at the expense of principles inclosed in its cotyledons. It gradually exhausts the vitelline substance contained in the umbilical vesicle. The emulsive substance of the reticulated sac of the allantoid pouch is also gradually absorbed. The end of the second month arrives; the vessels of the cord are formed and the placenta is developed; by its contact with the uterus, this organ obtains reparatory materials, elaborates them, and forms from them a fluid more or less analogous to blood, and this fluid is absorbed by the radicles of the umbilical vein.

We find, consequently, some of the most distinguished physiologists of the age denying—as it would seem that every one ought to deny—that the nutrition of the fœtus takes place solely by means of blood sent by the mother to the fœtus. If we search into the evidence afforded us by transcendental anatomy, we find that amidst the various singular monstrosities met with, there would appear to be but one thing absolutely necessary for fœtal developement,—an absording surface, surrounded by a nutritive substance capable of being absorbed. Head, heart,—everything, in short, except organic nervous system, vessels, and cellular tissue,—may be wanting, and yet the fœtus may grow so as to attain its ordinary dimensions.

We have the most incontestable evidence, that neither the placenta

nor umbilical cord is indispensably necessary for fœtal developement. Adelon disposes of this in the most summary manner, by affirming, that "there is no authentic instance of a fœtus, devoid of umbilical cord and placenta, attaining full uterine growth." The case is not, however, got rid of so easily. The marsupial animals breed their young without either placenta or cord. The embryos are inclosed in one or more membranes, which are not attached to the coats of the uterus, and are supplied with nourishment from a gelatinous matter by which they are surrounded. Thomas Bartholin, during his travels in Italy, saw an individual, forty years old, who was born without anus, penis, or umbilicus; and M. Velpeau cites cases from Ruysch, Samson, Chatton, Rommel, Denys, Fatio, V. Geuns, Sue, Penchienati, Franzio, Desgranges, Kluyskens, Pinel, Mason, Osiander, Dietrich, Von Froriep, and Voisin; but as these cases militate against his views of embryotrophy, he attempts to diminish their force by affirming, that the observations, which he had made, satisfy him, that all the fœtuses thus born had died in utero, in consequence of the destruction of the cord, or the closure of the umbilicus; or else, that the umbilicus existed, but was hidden or lost in the extroversion of the bladder, almost always remarked in those that lived. Now, passing by the singular deduction of M. Velpeau, that his observations have satisfied him of the incorrectness of observations made by men, many of whom have long since passed away,—long before he existed,—as well as the facts relating to the marsupial animal, and that the fœtus, in extra-uterine pregnancies has frequently no placenta,—with the case cited by Dr. Good, from Hoffmann, of a fœtus born in full health and vigour, with the funis sphacelated and divided into two parts; and one by Van der Wiel, of a living child, exhibited without any umbilicus as a public curiosity,—a case, observed by Dr. Good himself, appears to us to be impregnable. The case in question occurred in 1791. The labour was natural; the child, scarcely less than the ordinary size, was born alive; cried feebly once or twice after birth, and died in about ten minutes. The organization, both internal and external, was imperfect in many parts. There was no sexual character whatever; neither penis nor pudendum; nor any interior organ of generation. There was no anus, no rectum, no funis, no umbilicus. The minutest investigation could not discover the least trace of any. With the use of a little force, a small, shrivelled placenta,—or rather the rudiment of a placenta,—followed soon after the birth of the child, without a funis or umbilical vessel of any kind, or any other appendage by which it appeared to have been attached to the child. In a quarter of an hour afterwards, a second living child was protruded into the vagina and delivered with ease, being a perfect boy, attached to its placenta by a proper funis. The body of the first child was dissected in the presence of Dr. Drake of Hadleigh, and of Mr. Anderson of Sunbury, to both of whom Dr. Good appeals for the correctness of his statement. In the stomach, a liquid was found resembling the liquor amnii.

How could nutrition have been effected, then, in this case? Certainly not by blood sent from the mother to the child, for no apparatus for its conveyance was discoverable; and are we not driven to the necessity of supposing, that the food must have been obtained from the fluid within the ovum? This case,—with the arguments already adduced,—seems to constrain us to admit, that the liquor amnii may have more agency in the nutrition of the new being than is generally granted. Professor Monro, amongst other reasons,—all of which are of a negative character,—for his disbelief in this function of the liquor amnii, asserts, that if the office of the placenta be not that of affording food to the embryo, it becomes those, who maintain the contrary doctrine, to determine what other office can be allotted to it, and that till this is done, it is more consistent with reason to doubt the few and unsatisfactory cases, at that time brought forward, than to perplex ourselves with facts directly contradictory of each other. The case given by Dr. Good, since Professor Monro's remarks were published, is so unanswerable, and so unquestionable, that it affords a positive fact, of full or nearly full fœtal developement, independently of placenta and umbilical cord; and the fact must remain, although our ignorance of the functions of the placenta, be "dark as Erebus."*

* The following case, with which the author has been obligingly favoured by his friend, Dr. Wright, has an instructive bearing upon the subject. The condition of the placenta was such as to lead that intelligent observer to conclude, that any circulation between the mother and the fœtus, through the placenta, was impracticable.

Baltimore, *Sept.* 26*th*, 1835.

DEAR SIR.—In compliance with your request, I offer you the following plain and short statement of a case, which occurred in my practice, at the date indicated.—

On the 6th of December, 1833, I was requested to visit Mrs. T——, of this city,—a young woman of large form, good constitution, and generally excellent health. She had been married about fifteen months, and I was now called to attend her first labour. She had felt occasional labour pains through the day, and was delivered of a fine, vigorous, female infant, in about four hours from the time of my call. The labour was, in all respects, natural, and as easy, as is common,—or consistent—with a first parturition. After the birth of the child, an hour, perhaps, was passed in waiting for secondary pains to effect the expulsion or favour the removal of the placenta, but no movement of this kind having then occurred, a gentle examination was made to ascertain whether that body might be easily and properly taken away. The vagina contained nothing more than the funis,—the outlet of the uterus was open, soft and extensible. The cord was gently followed into the uterine cavity, and the cake found near its fundus, retaining a close connexion with the uterus. The placental mass was large and firm, presenting to the touch a peculiar feeling—as of a dense sponge, full of coarse, granular or gravelly particles. Deeming it now proper to relieve the patient fully, a cautious effort was made to detach the placenta from the uterus, in order to its manual extraction. In pursuing this design, it was found, that the adhering surface of the former consisted of a uniform calcareous lamina, or plate, rough to the finger, and exciting such a sensation or feeling, as would be caused by a sheet of coarse sand paper. When the mass was detached, and brought away, the laminar surface just referred to, was found to be a calcareous plate, uniformly covering the whole of the attached portion of the cake,—the entire surface of the utero-placental connexion. The calcareous matter, thus distributed, was thin and readily friable, but, as before remarked, it appeared to constitute a uniform superficial covering. The correspondent uterine sur-

Amongst those physiologists, who admit the liquor amnii to be a fluid destined for fœtal nutrition, a difference prevails, regarding the mode in which it is received into the system. Buffon, Osiander, Fohmann and others think, that it is absorbed through the skin. In the fœtal state, the cuticle is extremely thin; and, until within a month or two of the full period, can be scarcely said to exist. There is consequently not that impediment to cutaneous absorption, which, we have seen, exists in the adult. The strong argument, however, which they offer in favour of such absorption is the fact, that the fœtus has been found developed, although devoid of both mouth and umbilical cord; and Professor Monro, in opposing the function ascribed to the liquor amnii, refers to cases of monstrous formation, in which no mouth existed, nor any kind of passage leading to the stomach.

Others, as Boerhaave and Haller, are of opinion, that the fluid enters the mouth and is sent on into the stomach and intestines; and in support of this view they affirm, that the liquor amnii has been found in these viscera;—that it has been shown to exist in the stomach and pharynx. Heister on opening a gravid cow, which had perished from cold, found the liquor amnii frozen, and a continuous mass of ice extending to the stomach of the fœtus.

The physiologists, who believe that the liquor amnii is received into the stomach, differ as to what happens to it in that organ. Some suppose, that it is simply absorbed without undergoing digestion; others, that it must first be subjected to that process. According to the former opinion, it is simply necessary, that the fluid should come into contact with the mucous membrane of the alimentary passages; and they affirm, that if digestion occur at all, it can only be during the latter months. Others, however, conceive, that the waters are swallowed or sucked in, and that they undergo true digestion. In

face—the part from which the placenta had been separated—felt rough, but comparatively soft, imparting nothing, distinctly, of the calcareous or gritty feel. Out of the body, the placenta felt heavy, and eminently rough throughout. When compressed, or rubbed together, the large amount of nodular or granular matter, dispersed through its substance, was not only manifest to the touch, but a very audible crepitation or grating sound could be thus elicited from any, and every part of the mass.

In this uncommon instance of placental degeneracy, both the mother and child were perfectly healthy and well.—The latter, indeed, was remarkable for its fine size, perfect nutrition, and vigour. From the condition of the cake, and the character of its adhesion to the uterus, I apprehended a more than ordinary liability to secondary affection, in the form of puerperal fever,—and, whether influenced or not, by the circumstances detailed, secondary fever did ensue on the third day from delivery, attended by the usual signs of puerperal hysteritis, which affection, however, was happily subdued by general and topical bleeding, calomel, &c.

With sincere regard, Yours.

T. H. Wright.

Professor Dunglison.

P. S.—The child, referred to, is living, and, from its birth to the present, has considerably exceeded the common bulk of children at the same age. The mother is now far advanced in her second pregnancy.

evidence of this, they adduce the fact of meconium existing at an early period in the intestinal canal, which they look upon as evidence that the digestive function is in action; and in farther proof of this they affirm, that on opening the abdomen of a new-born infant the chyliferous vessels were found filled with chyle, which could not, they say, have been formed from any other substance than the liquor amnii; and lastly, that fine silky down has been found in the meconium, similar to that which exists on the skin of the fœtus, and which is conceived to have entered the mouth along with the liquor amnii.

These reasons have their weight, but they cannot explain the developement in the cases above alluded to, in which there was no mouth; and of course they cannot apply to acephalous fœtuses. Moreover, it has been properly remarked, that the presence of meconium in the intestinal canal—admitting that it is the product of digestion, which is denied by many—merely proves that digestion has taken place, and the same may be said of the chyle in the chyliferous vessels: neither one nor the other is a positive evidence of the digestion of the liquor amnii. Both might have proceeded from the stomachal secretions. It has also been affirmed that the meconium exists in the intestines of the acephalous fœtus, and in those in which the mouth is imperforate. Lastly, with regard to the down discovered in the meconium, it has been suggested as possible that it may be formed by the mucous membrane of the intestine, which so strongly resembles the skin in structure and functions.

Others have supposed, that the liquor amnii is received by the respiratory passages, from the circumstance that, in certain cases, the fluid has been found in the trachea and bronchi; some presuming, that it readily and spontaneously enters at the nostrils and passes to the trachea and bronchi; others, that it is forced in by the pressure of the uterus; and others, again, that it is introduced by the respiratory movements of the fœtus.

Views have differed in this case, also, regarding the action exerted upon it after introduction;—some presuming that it is absorbed immediately; others, that it is inservient to a kind of respiration; and that, during fœtal existence, we are aquatic animals,—consuming the oxygen or atmospheric air, which Scheele and others have stated to exist in the fluid. It is scarcely necessary to oppose seriously these gratuitous speculations. The whole arrangement of the vascular system of the fœtus, so different from that which is subsequently established, and the great diversity in the lungs, prior and subsequent to respiration, would be sufficient to refute the idea, had it even been shown that the liquor amnii always contains one or other of these gases, which is by no means the fact. The case of the acephalous fœtus is also an obstacle to this view as strong as to that of the digestion of the liquor amnii.

As if to confirm the remark of Cicero—"nihil tam absurdum, quod non dictum sit ab aliquo philosophorum,"—it has been ad-

vanced by two individuals of no mean pretensions in science, that the liquor amnii may be absorbed by the genital organs or by the mammæ. Lobstein supports the former view; Oken the latter. Lobstein asserts, that the fluid is laid hold of by the mammæ, is elaborated by them, and conveyed from thence into the thymus gland, the thoracic duct, and the vascular system of the fœtus!

Of these various opinions, the one that assigns the introduction of the fluid to the agency of the cutaneous absorbents appears to carry with it the greatest probability. It must be admitted, however, that the whole subject is environed with obscurity, and requires fresh, repeated, and accurate experiments and observations to enlighten us.

But it may now be asked, with Monro, what are the nutritive functions performed by the placenta? We have before alluded to the different views, entertained regarding the connexion between the placenta and the uterus. Formerly, it was universally maintained, that vessels pass between the mother and maternal side, of the placenta, and that others pass between the fœtus and the fœtal side, but that the two sides are so distinct, as to justify their being regarded as two placentæ,—the one maternal, the other fœtal,—simply united to each other.

At one time, again, it was supposed, that a direct communication exists between the maternal and fœtal vessels, but this notion has long been exploded. We have decisive evidence, that the connexion is of the most indirect nature. Wrisberg made several experiments, which showed that the fluid of the fœtal circulation is not drained when the mother dies from hemorrhage. It has been affirmed, too, that if the uterine arteries be injected, the matter of the injection passes into the uterine veins after having been effused into the lobes of the placenta, and the same thing happens when the uterine veins are injected. If, on the other hand, the injection be thrown into the umbilical arteries or vein, the matter passes from one of these sets of vessels into the other, is effused into the fœtal side of the placenta, but does not pass into the uterine vessels. When, however, an odorous substance, like camphor, is injected into the maternal veins of an animal, the fœtal blood ultimately assumes a camphorated odour. Magendie injected this substance into the veins of a gravid bitch, and extracted a fœtus from the uterus at the expiration of three or four minutes: the blood did not exhibit the slightest odour of camphor; whilst that of a second fœtus, extracted at the end of a quarter of an hour, had a decidedly camphorated smell. This was the case, also, with the other fœtuses. Such communication may, however, have been owing to the same kind of transudation and imbibition, of which we have spoken under the head of absorption, and may consequently be regarded as entirely adventitious; and the fact of the length of time, required for the detection of the odorous substance, favours this idea; for if any

direct communication existed between the mother and the fœtus, the transmission ought certainly to have been effected more speedily.

The transmission of substances from the fœtal to the maternal placenta is yet more difficult. Magendie was never able to affect the mother by poisons injected into the umbilical arteries and directed towards the placenta; and he remarks, in confirmation of the results of the experiments of Wrisberg, that if the mother dies of hemorrhage, the vessels of the fœtus remain filled with blood.

They who consider, that there is no maternal and fœtal portion of the placenta, or rather, that it is all fœtal, of course believe, where the matter of injection, thrown into the uterine vessels has passed into the cells of the placenta, that it has been owing to rupture of parts, by the force with which the injection has been propelled.

Another fact, that proves the indirect nature of the connexion which exists between the parent and child, is the total want of correspondence between the circulation of the fœtus and that of the mother. By applying the stethoscope to the abdomen of a pregnant female, the beating of the fœtal heart is observed to be twice as frequent as that of the mother. Again; examples have occurred in which the fœtus has been extruded with the placenta and membranes entire. In a case of this kind, which occurred to Wrisberg, the circulation continued for nine minutes; in one, described by Osiander, for fifteen minutes; in some, by Professor Chapman, for from ten to twenty minutes; and in one by Professor Channing, of Boston, and Dr. Selby, of Tennessee, where a bath of tepid water was used to resuscitate the fœtus, for an hour. In other cases of a similar kind, where the child could scarcely breathe and was in danger of perishing, the life of the placenta has been maintained by keeping it in water of a temperature nearly equal to that of the body, and the child has been saved. All these facts prove demonstratively, that the fœtus carries on a circulation independently of that of the mother; and whatever passes between the fœtal and maternal vessels is probably exhaled from the one and absorbed by the other, as the case may be. The fluid sent to the fœtus is supposed by some, —indeed by most physiologists,—to be the maternal blood, modified or unmodified. Schreger, however, and others maintain, that the communication of any nutritious fluid from the mother to the fœtus and conversely takes place by means of lymphatics, and not by blood-vessels; and that the maternal vessels exhale into the spongy tissue of the placenta the serous part of the blood, which is taken up by the lymphatics of the fœtal portion, and conveyed into the thoracic duct.

It has been before remarked, that Lobstein and Meckel suppose, that the gelatinous substance of the cord is one of the materials of fœtal nutrition. This opinion they found on the circumstance of the albuminous nature of the substance, and the great size which it gives to the cord at the early periods of fœtal life, as well as on the great developement of the absorbent vessels of the fœtus, that pro-

ceed from the umbilicus to the anterior mediastinum; whilst others invoke, also, the fluids of the umbilical and allantoid vesicles. All these speculations regarding the various sources of nutritive matter are sufficient evidence of the uncertainty that prevails on this interesting topic.

It is manifest that we cannot regard as nutritrive matters those substances which are secreted by the fœtus itself. It is impossible that any developement can occur without the reception of materials from without. We have seen, that when the ovum passes from the ovarium to the uterus, it contains within it a molecule, and fluids which are probably destined for the nutrition of the new being, and which afford the necessary pabulum for the increase, that occurs between impregnation and the period at which an adhesion is formed between the ovum and the inner surface of the uterus. The mother, having furnished the nutritive material in the ovum, she must continue to provide it in the uterus; and so soon as a vascular communication is formed between the exterior of the ovum and the interior of the uterus, nutritive elements are doubtless received by the embryo;—for otherwise it would perish from inanition. What then can be the nature of these elements? Do they consist of maternal blood, laid hold of by the fœtus at this early period, when no circulatory system is apparent: or are the blood-vessels distributed to the membranes of the ovum, to enable them to continue the secretion of that nutritive matter which they took with them from the ovarium, and which must necessarily have had a maternal origin? The latter certainly is the more probable supposition, and it is, as we have seen, an argument in favour of the amnion being supplied with blood from the uterus, rather than from the fœtus; for, if we admit it to be in any manner inservient to nutrition, its production must be extraneous to the body which it has to nourish. These observations apply equally to the jelly of the umbilical cord, which is probably secreted by the membranous envelopes, and may consequently be regarded as a nutritive material derived from the parent. Both, it is true, might be secreted by the fœtus from fluids furnished by the mother, and be placed in depot, as the fat is in after existence.

Transcendental anatomy, then, instructs us, that placenta and umbilical cord are not indispensable to fœtal nutrition; and compels us to infer, with Meckel—one of the most eminent of modern anatomists and physiologists—that the human placenta may have no direct agency in embryotrophy. We are, therefore, necessarily driven to the conclusion, before laid down,—that, in order that a fœtus shall be developed in utero, it is but necessary, that there shall be an absorbing surface, surrounded by a nutritive substance, which will admit of being absorbed. Now, the cutaneous envelope of the fœtus—monstrous or natural—is such a surface, and the liquor amnii such a fluid; whilst the matter of the umbilical vesicle and the jelly of the cord, when these parts exist, and *possibly* some

material derived through the placenta—after it exists—may lend their aid; but the participation of these last agents is—to say the least—doubtful. The function of the placenta probably is, to admit of the fœtal blood being *shown* to that circulating in the maternal vessels, so that some change may be effected in the former, which may better adapt it for serving as the pabulum, whence the secretions, from which the fœtal organs have to be elaborated, must be formed.

If we admit this, however, it is obvious, that the nutritive fluid, when received into the system, will have to be made into blood by the action of the fœtus, in a manner, bearing some analogy to what occurs in the adult, or in the simplest of living beings, in which the nutritive fluid is absorbed at the surface of the body. Of the mode in which such conversion is effected we are in the same darkness, that envelopes all the mysterious processes which are esteemed organic and vital; but that the fœtus is capable of effecting it we have irrefragable proof in the oviparous animal, where there can be no communication, after the egg is laid, between the embryo and the parent. Yet we find it forming its own blood from the yolk surrounding it, and undergoing its full and regular developement from causes seated in itself alone.

Of those physiologists, who consider that the mother sends her blood to the placenta, to be taken up by the fœtal vessels, all do not conceive that it is in a state adapted for the nutrition of the new being: some are of opinion that the placenta or the liver, or both, modify it, but in a manner which they do not attempt to explain. In favour of such an action being exerted by the placenta, they state that it is clearly the organ which absorbs the fluid, and that every organ of absorption is necessarily one of elaboration;—a principle which we have elsewhere proved to be unfounded; and, moreover, that the blood, conveyed to the fœtus by the umbilical vein, differs essentially in colour from that conveyed to it by the umbilical arteries,—a fact, which we shall see, can be accounted for more satisfactorily. In support of the view, that a second change is effected in the liver, they affirm, that a great part of the fœtal blood ramifies in the substance of that organ before it reaches the heart; a part only going by the ductus venosus; and that the great size of the liver, during fœtal life, when its function of secreting bile can be but sparingly exerted, is in favour of this notion.

The opinion, that some change is effected upon the blood in the liver, is certainly much more philosophical and probable than the belief of Haller, that the object of its passage through that organ is to deaden the force with which the mother projects the fluid into the fœtal vessels. We have seen, that it is extremely doubtful, whether she transmits any; and that if she does, the communication is very indirect.

M. Geoffroy Saint-Hilaire appears to think, that the blood of the mother, which he conceives to be sent through the placenta to the

fœtus, is unfitted for fœtal life, before it has undergone certain modifications. The blood, according to him, which leaves the placenta, proceeds in part to the liver and the remainder to the heart. In the liver it forms the material of the biliary secretion, or at least of a fluid, which, when discharged into the intestines, irritates them, and provokes a copious secretion from the mucous or lining membrane. This mucus, according to M. Saint-Hilaire, is always met with in the stomach and intestines of the fœtus; whilst the presence of meconium, and of other excrementitious matters in the intestines, shows, that digestion must have taken place. This digestion he considers to be effected upon the mucus, secreted in the manner just mentioned; and, in support of its being inservient to sanguification, he affirms, that its quantity is too great for the simple purpose of lubricating the parts; that mucus is the first stage of all organic compounds; that it predominates in all young beings; is the foundation of every organ; more capable of assimilation than any other substance, &c. But independently of the whole of this view being entirely hypothetical, it cannot be esteemed probable, that the fœtus is nourished by one of its own secretions. All secretions must be formed from blood. Blood must, therefore, pre-exist in the fœtal vessels, and the process, indicated by Saint-Hilaire, be unnecessary.

Allusion has already been made to the opinions of Schreger, on the nutrition of the fœtus. These were developed in a letter written by him, in 1799, to Sömmering. He considers, that all communication of nutritious matter between the mother and fœtus occurs through the lymphatics which he has described as existing in considerable numbers in the placenta and umbilical cord. The red blood, flowing in the maternal vessels, is too highly charged with carbon, and with other heterogeneous substances, he thinks, to serve for the nutrition of the fœtus. Its serous part, which is purer and more oxygenized, is therefore alone exhaled. The uterine arteries pour this serum into the spongy texture of the placenta, whence it is taken up by the lymphatics of the fœtal portion. These convey it along the umbilical cord to the thoracic duct, whence it passes into the left subclavian, vena cava superior, right auricle and ventricle, ductus arteriosus, aorta; and, by the umbilical arteries, is returned to the placenta. In this course, it is mixed with the blood, and becomes itself converted into that fluid. When it attains the placenta, the blood is not poured into the cells of that organ, to be transported to the mother, but it passes into the umbilical vein, the radicles of which are continuous with the final ramifications of the umbilical arteries. Lateral pores, however, exist in the latter, which suffer fluids to escape, that cannot be elaborated by the fœtus, or which require to be again submitted to the maternal organs, before they are fitted for its support. These fluids, according to Schreger, are not absorbed by the veins of the uterus, but by the lymphatics of that viscus, which are so apparent in the pregnant state, and have been injected by Cruikshank, Meckel, &c. In his view, therefore,

the conversion of the serous fluid into blood is chiefly effected in the lymphatic system, and it has been a favourite hypothesis with many physiologists, that those organs, regarding whose functions we are so profoundly ignorant, and whose developement is so much greater during intra-uterine than extra-uterine existence,—as the thymus, and thyroid glands, and the supra-renal capsules,—are, in some way, connected with the lymphosis or hæmatosis of the fœtus. We have already referred to the conjectures, that these organs are diverticula for the blood of those parts, the functions of which are not exerted until an after period of existence. Broussais makes the thyroid a diverticulum to the larynx; the thymus a diverticulum to the lungs, and the supra-renal capsules to the kidneys. Notwithstanding these ingenious speculations, however, our darkness, with regard to the true functions of these singular organs, is not the less impenetrable.

To conclude. The most plausible opinion we can form on this intricate subject is, that the mother secretes the substances, which are placed in contact with the fœtus, in a condition best adapted for its nutrition; that in this state they are received into the system, by absorption, as the chyle or the lymph is received in the adult,—undergoing modifications in their passage through the fœtal placenta, as well as in every part of the system, where the elements of the blood must escape for the formation of the various tissues.

With regard to the precise nutritive functions executed in the fœtal state, and first as concerns *digestion*, it is obvious, that this cannot take place to any extent, otherwise excrementitious matter would have to be thrown out, which, by entering the liquor amnii, would be fatal to many important functions, and probably to the very existence of the fœtus. Yet, that some digestion is effected, is manifest from the presence of meconium in the intestines, which is probably the excrementitious matter, arising from the digestion of the mucous secretions of the alimentary canal.

Respiration, as accomplished by lungs, does not exist; and we have already seen, that the idea of the fœtus possessing the kind of respiration of the aquatic animal is inadmissible. An analogous function to the respiration of the adult, however, occurs, as respects the changes effected upon the blood. It is probable that the blood is sent to the placenta to be aerated there, as it is in the lungs in extra-uterine existence. Such was the opinion of Sir Edward Hulse, of Girtanner, Stein, and we may say, such is the opinion of many of the most enlightened physiologists of the present day. The chief arguments, adduced in support of this opinion, are,—the absolute necessity for air to every living being, animal or vegetable; the no less necessity for a free circulation of blood—along the umbilical cord to and from the placenta—to the life of the fœtus; the analogy of birds, in which the umbilical vessels are inservient to respiration by receiving the external air through the pores of the

shell, so that if the shell be covered with varnish, respiration is prevented, and the chick dies.

The sensible evidences of these changes being effected by the placenta are not like those, which we possess regarding the aeration of the blood in its passage through the lungs of the adult, where the venous differs so essentially from the arterial blood. It is indeed asserted, in works of anatomy, that "the effete blood of the umbilical arteries becomes regenerated in the placenta, assumes a brighter hue, and is returned to the fœtus by the umbilical vein," but this is not in accordance with experiment and observation. Bichat made numerous dissections of young pigs whilst still in utero, and he uniformly found the blood of the arteries and veins presenting the same appearance and resembling the venous blood of the mother. Not the slightest difference was observed between the blood of the aorta and that of the vena cava, nor between that of the carotid artery and of the jugular vein. He made the same observations in three experiments of a similar kind on the fœtuses of the dog. He also frequently examined human fœtuses that had died in utero, and always found the same uniformity between the arterial and venous blood: hence he concludes, that there is no difference between the arterial and the venous blood of the fœtus, at least in appearance. Similar experiments by Autenrieth furnished the same results. It is important to bear this fact in mind, inasmuch as it may be received as one of the evidences that a fœtus has not respired.

The apparent identity, however, between the blood passing to the placenta by the umbilical arteries and that returning by the cord is not real. The slightest reflection will show, that they must be different. It is from the blood, carried by the umbilical vein and distributed over the body, that all the organs of the fœtus have to derive the materials of their nutrition and developement; and, being deprived of these materials, the fluid must necessarily be different in the umbilical arteries from what it is in the umbilical vein. The researches of more modern chemistry have not been directed to the fœtal blood, but Fourcroy analyzed it, and found it to differ materially from the blood of the child that had respired. He asserts, that its colouring matter is darker, and seems to be more abundant; that it is destitute of fibrine and of phosphoric salts, and is incapable of becoming florid by exposure to the influence of atmospheric air. Under the head of circulation it was remarked, that the coloration of the blood is perhaps of no farther importance than as indicating that the vital change of aeration has taken place in the lungs. In this case, we have the vital change effected without any such coloration. Yet how, it may be asked, is the modification in the blood produced where no placenta and no umbilical cord exist? And can we suppose that in such cases the aeration is effected by the liquor amnii containing an unusual quantity of oxygen, as has been presumed by some physiologists? These are

embarrassing questions—more easily propounded than answered. By some, it has been presumed, that the liver, even in the adult, performs a function supplementary to that of the lungs, and the great size of the organ, in the fœtus, has been conceived to favour the idea, that it may separate carbon and other matters freely from the system, and, in this way, be depuratory: but the grounds for this presumption are not, we think, strong.

It is in the *fœtal circulation* that we observe the most striking peculiarities of intra-uterine existence. Of its condition at the very earliest periods we know little that is not conjectural. We will, therefore, consider it as it is effected during the last months of utero-gestation. From the sketch already given of the circulatory organs of the fœtus, it will be recollected,—1st, that the two auricles of the heart communicate by an aperture in the septum, called the *foramen ovale*, which has a valve opening towards the left ventricle; 2dly, that near the orifice of the vena cava inferior is the *valve of Eustachius*, so situated as to direct the blood of the cava into the foramen ovale; 3dly, that the pulmonary artery has a vessel passing from it into the aorta,—the *ductus arteriosus;* 4thly, that two arteries, called *umbilical*, proceed from the internal iliacs to the umbilicus and placenta; and, lastly, that the *umbilical vein* from the placenta pours part of its blood into the vena porta; and a part passes by the *ductus venosus*,—a fœtal vessel,—into the inferior cava.

The course of the circulation, then, is as follows:—The blood of the umbilical vein,—the radicles of which communicate with those of the umbilical arteries in the placenta,—proceeds along this vein to the umbilicus, and thence to the liver. A part of this traverses the ductus venosus, enters the vena cava inferior, and becomes mixed with the blood from the lower parts of the fœtus; the remainder passes into the vena porta, is distributed through the liver, and, by means of the hepatic veins, is likewise poured into the vena cava. In this manner it attains the right auricle. Owing to the arrangement of the valve of Eustachius, the blood passes immediately through the foramen ovale into the left auricle,—without being mixed with the fluid proceeding from the upper parts of the body into the right auricle through the vena cava superior. The left auricle is consequently as much developed as the right, which it would scarcely be, did it receive only the blood from the lungs. Were it not as large, it is obvious, that it would be insufficient to carry on the circulation, when the whole of the blood passes through the lungs, and is poured into it after respiration is established.

The above are the opinions of Wolf and Sabatier regarding the use of the Eustachian valve. According to this view, if the valve did not exist, the aerated blood, conveyed to the heart by the ductus venosus, instead of being directed into the left auricle through the foramen ovale, would pass into the right auricle, and thence,—in part, at least,—into the right ventricle; from which it would be transmitted, through the pulmonary artery and ductus arteriosus, into the

descending aorta; so that no part of the body, above the opening of the duct into the aorta, could receive the aerated blood, whilst much of that, which passed along the aorta, would be returned to the placenta by the umbilical arteries. But as the blood is directed into the left auricle by the Eustachian valve, it passes from thence into the left ventricle, and is forced by it into the aorta, which distributes it to every part of the system, and thus conveys the regenerated fluid to every organ. Dr. Wistar has also suggested, that, without this arrangement of the Eustachian valve, the coronary arteries, distributed to the heart, would be unfit for supporting the life of that organ, inasmuch as they would be deprived of a regular supply of revivified blood.

From the left auricle, the blood passes into the left ventricle, and from the left ventricle into the ascending aorta and to the upper parts of the body, from which it is brought back, by the vena cava superior, into the right auricle; thence it is transmitted into the right ventricle, and, by the contraction of the ventricle, into the pulmonary artery. By this vessel it is sent,—the greater part through the ductus arteriosus into the descending aorta, and a small part to the lungs. From the lungs, it is returned into the left auricle by the pulmonary veins. Through the descending aorta, the blood, conveyed in part by the ductus arteriosus, and in part by the contraction of the left ventricle, is distributed, partly to the lower extremities, from which it is returned by corresponding veins into the vena cava inferior, and partly by the umbilical arteries to the placenta.

This view of the circulation supposes,—what is disputed,—that the blood of the vena cava superior and of the vena cava inferior does not undergo admixture in the right auricle; whence it would follow, that some parts of the body receive a purer blood than others, —the upper parts, as the head and neck, receiving that, which flows immediately from the placenta, whilst the lower parts do not obtain it until it has circulated through the upper. Under any view it is manifest, that it is not the whole of the blood, which is distributed to the organ of aeration, as in the adult, but a part only as in the batrachia.

Bichat and Magendie contest the explanation of Wolf and Sabatier, regarding the use of the valve of Eustachius and the non-admixture of the blood of the two cavæ in the right auricle. In their opinion, the two bloods do commingle; but—owing to the existence of the foramen ovale, and the arrangement of the valve of Eustachius—the left auricle is filled simultaneously with the right; and, consequently, the same kind of blood must be distributed to both the upper and lower portions of the body. The uses of the foramen ovale and ductus arteriosus are explained as follows. As the left auricle receives but little blood from the lungs, it could furnish but a small quantity to the left ventricle, did it not receive blood through the foramen ovale; and, again, as the lung is exerting no function, during the state of fœtal life, the blood is sent along the pulmonary

artery and ductus arteriosus into the aorta, so that the contraction of both ventricles is employed in propelling the blood along the aorta to the lower parts of the body and to the placenta. Without this union of forces, it is conceived, that the blood could not be urged forward as far as the placenta.

Recent experiments, by Dr. John Reid,—the detail of which forms part of some select cases and communications from the Transactions of the Medico-Chirurgical Society of Edinburgh,—favour the views of Wolf and Sabatier. He took a fœtus of about seven months, and threw simultaneously a red-coloured injection up the vena cava inferior, and a yellow-coloured one down the vena cava superior. On tracing the red injection upwards, it was found to have passed through the foramen ovale and to have filled the left side of the heart, without any intermixture with the yellow, except very slightly at the posterior part of the right auricle. Not a drop of the yellow appeared to have accompanied the red into the left side of the heart. From the left side of the heart it ascended the aorta, and filled all the large vessels going to the head and upper extremities. The injection, in all these vessels, had not the slightest tinge of yellow.

On tracing the yellow injection downwards, he found it filling the right auricle and the right ventricle, whence it proceeded along the pulmonary artery, and filled the ductus arteriosus, and branches going to the lungs. On entering the aorta, it passed down that vessel, filling it completely without any admixture of red, so that all the branches of the thoracic and abdominal aorta were filled with yellow. From this and other experiments of a similar kind, Dr. Reid infers, that the blood, returning from the placenta, passes principally to the head and upper extremities; and that the lower part of the body is principally supplied by blood returning by the vena cava superior; or, in other words, by blood which has already gone the circuit in the body.

After all, the great difference between the fœtal and adult circulation is,—that, in the former, a part of the blood only proceeds to the organ of sanguification; that the aerated blood is poured into the right auricle instead of the left; that, instead of proceeding through the lungs, a part of the blood gets at once to the left side of the heart, whence it is sent to the head and upper extremities, and the remainder goes directly from the pulmonary artery into the aorta; that a part of the aortic blood proceeds to the lower extremities, and the remainder goes to the placenta, from which it is returned into the inferior cava.

With regard to the *nutrition*, (properly so called,) of the fœtus, it is doubtless effected in the same manner as in the adult; and our ignorance of the precise nature of the mysterious process is equally great. During the whole of fœtal existence, it is energetically exerted, and especially during the earlier periods. Sömmering has asserted, that the growth of the fœtus fluctuates; that in the first month it is greatest; in the second, less; in the third, greater; less,

again, in the fourth; and then greater until the sixth, when it diminishes until birth.

There is a singular circumstance, connected with the nutrition of the fœtus, which cannot be passed over without a slight notice, although, in its details, it belongs more properly to pathologicd anatomy.

Owing to inappreciable causes, the different parts of the fœtus, or some particular part, may be preternaturally developed or be defective, giving rise to what have been termed *monstrosities.* Three kinds of monsters may be considered to exist. The *first* comprises such as are born with an excess of parts, as with two heads on one trunk, two trunks to one head; with four arms and four legs; twins with a band uniting them, as in the case of the Siamese twins, &c. The *second* includes those in which parts are defective, as acephali, anencephali, &c.; and the *third*, those in which there is deviation of parts, as where the heart is on the right side, the liver on the left, &c.; where, in other words, there is *transposition of the vicera.* In these cases respectively, there is—to use the language of the German pathologists *superabundant*, *defective* or *perverted* action of the force of formation—the Bildungstrieb—to which we have more than once alluded.

The hypotheses, that have been advanced to account for these formations, as well as for those in which the parts are irregularly developed, may be reduced to three; the others, that have been entertained, having no probability in their favour. *First.* They have been attributed to the influence of the imagination of the mother over the fœtus in utero. *Secondly.* To accidental changes, experienced by the fœtus at some period of uterine existence; and *Thirdly.* To some original defect or confusion of the germs.

The first of these causes has been a subject of keen controversy amongst physiologists, at all periods. We have seen, that the mother transmits to the fœtus the materials for its nutrition; and that, to a certain extent, the nutrition is influenced by the character of the materials transmitted; so that if these be not of good quality or in due quantity, the fœtus will be imperfectly nourished, and may even perish. Any violent mental emotion may thus destroy the child, by modifying the quantity or quality of the nutritive matter sent to it. Small-pox, measles, and other contagious diseases can also be unquestionably communicated to the fœtus in utero; so that the life of the fœtus is indirectly but largely dependent upon the condition of the mother. But the maternal influence has been conceived to extend much beyond this; and it has been affirmed, that the excited imagination of the mother may occasion an alteration in the form of particular parts of the fœtus, so as to give rise to *nævi* and to all kinds of *mothers' marks*, as they have been termed.

These may consist of spots resembling raspberries, grapes, &c.; or there may be deficient formation of particular parts,—and some of the cases, that have been adduced in favour of their having been

induced by impressions, made upon the mother during pregnancy, are sufficiently striking. There are numerous difficulties, however, in the way of accepting the cause assigned. If a child be born with nævi of any kind, the recollection of the mother is racked to discover, whether some event did not befall her during gestation to which the appearance can be referred, and it is not often difficult to discover some plausible means of explanation.

Cases have occurred in which the mother, when a few months advanced in pregnancy, has been shocked by the sight of a person who had lost his hand, and the child has been born devoid of a hand. A young female, a few months gone with child, visited a brother in one of the hospitals of London who was wounded in the side. His condition affected her extremely. Her child was born with a deep pit precisely in the same part that was wounded in the brother.

These are samples of the thousands of cases that have been recorded, or that have occurred to different individuals. Similar instances have even been related of the inferior animals. In the extracts from the minute book of the Linnean Society of London, an account is given, by Mr. George Milne, F. L. S., of the effect of the imagination of a female cat on her young. One afternoon, whilst Mr. Milne and his family were at tea, a young female cat, which had arrived at the middle of gestation, was lying on the hearth. A servant, by accident, trod very heavily on her tail; she screamed violently, and, from the noise emitted, it was evident, that a considerable degree of terror was mingled with the feeling from the injury. From so common a circumstance no extraordinary result was expected; but, at the full time, she dropped five kittens, one of which was perfect, but the other four had the tail remarkably distorted; and all distorted in the same manner.

Are we to consider these and similar cases of malformation or monstrosities to be dependent upon the influence of the maternal imagination upon the fœtus in utero? or are we to regard them as coincidences, the cause being inappreciable, but such as we find to give occasion to vicious organization, where no coincidence with excited imagination can be discovered? Under the head of generation we have combated the notion, that the mother's fancy can have any effect—as to sex or likeness—during a fecundating copulation. Let us see, then, what we have to admit in a case where a female is, we will suppose, four months advanced in pregnancy, when she is shocked at the appearance of one, who has lost his arm, and the child is born with the like defect. It has been seen, that the communication between the mother and the fœtus is of the most indirect character; that the circulation of the fœtus is totally distinct from that of the mother; and that she can only influence the fœtus through the nutritive material she furnishes—whatever be its character—and consequently that such influence must be exerted upon the whole of the fœtus and not upon any particular part. Yet, in

the supposititious case we have taken, the arm must have been already formed, and the influence of the mother's fancy must have been exclusively exerted upon its absorbents, so as to cause them to take up again that which had been already deposited!

The case we have assumed is not environed with more difficulty than any of the kind. It is a fair specimen of the whole. Yet how impracticable for us to believe, that the effect can be in any way connected with the assigned cause; and how much more easy to presume, that the coincidence, in such cases, has been accidental. Cases of hare-lip are perpetually occuring, yet we never have the maternal imagination invoked; because, it is by no means easy to discover any similitude between the affection and extraneous objects. Moreover, in animals of all kinds—even in the most inferior, as well as in plants—monstrous formations are incessantly happening where maternal imagination is out of the question. As a cause of monstrosities, therefore, the influence of the maternal imagination has been generally regarded as an inadmissible hypothesis. By many, it has been esteemed ridiculous; yet it manifestly receives favour with Sir Everard Home, and is perhaps hardly worthy of the strong epithets of condemnation that have been applied to it; although sufficiently incredible.

The third hypothesis, with regard to defective germs, we have already canvassed under generation, and attempted to prove it insufficient. The second, consequently, alone remains, and is almost universally adopted. Independently of all disturbing influences from the mother, the fœtus is known to be frequently attacked with spontaneous diseases, such as dropsy, ulceration, gangrene, cutaneous eruptions, &c. Some of these affections occasionally destroy it before birth. At other times, it is born with them; and hence they are termed *connate* or *congenital.*

Where a part has been wanting, the nerve or blood-vessel or both, proceeding to it, have likewise been found wanting; so that the defect of the organ has been thus explained; without our being able, however, to understand the cause of the deficiency of such nerve or blood-vessel.

In some of the cases of monstrosities a confusion of two germs seems to have occurred. Two vesicles have been fecundated, and subsequently commingled, so that children have been produced with two heads and one trunk, or with two trunks and one head, &c. &c. At times, too, where two ova appear to have been fecundated, the developement of the one has been arrested, whilst the other has gone on. To instances of this kind we have alluded under the heads of superfœtation, and the theory of generation by evolution.

This interesting department of pathological anatomy has become, of late years, of deep interest as elucidating the laws of the formation of the animal body. The labours of Geoffroy Saint-Hilaire, Serres, Sömmering, Meckel, Tiedemann, Béclard, Breschet and others have, indeed—as Cuvier remarked respecting some of them—oc-

casioned the accumulation of an infinity of facts and views, which, even if we do not admit all that their authors contend for, cannot fail to be of solid advantage to science.

The *animal temperature* of the fœtus cannot be rigidly determined. The common belief is, that it is some degrees lower than that of the mother; and it is affirmed, that the temperature of the dead fœtus is higher than that of the living. The fœtus must, therefore, possess the means of refrigeration. Edwards found, in his experiments, that the temperature of young animals is inferior to that of the adult; which is in accordance with the general belief regarding that of the fœtus in utero. In some cases; as in those of the kitten, puppy and rabbit, if they be removed from the mother and exposed to a temperature of between 50° and 70°, their temperature will sink,—as happens to the cold-blooded animal,—to nearly the same degree. The faculty of producing heat he found to be at its minimum at birth; but it progressively increased, until in about fifteen days the animal acquired the power in the same degree with the adult. This was not the case, however, with all the mammalia. It seemed to be confined to those animals that are born blind; in which a state of imperfection probably exists in other functions. It was the same with birds as with the mammalia: birds, hatched in a defective state, as regards their organs generally, have the power of producing heat defective; whilst others, born in a more perfect condition, have the organs of calorification more capable of exercising their due functions. The opinions with regard to the temperature of the human infant vary. Haller asserts that it has less power of producing heat than the adult, and such is the opinion of Despretz, Edwards, and the generality of physiologists. The latter gentleman estimates it at 94.25° of Fahrenheit. On the other hand Dr. John Davy affirms, that the temperature of young animals generally, and that of a new-born child, which he particularly examined, was higher than in the adult. It is impossible to account for this discordance; but the general results of experiments will be found to agree with those of Edwards. The fœtus certainly possesses the power of forming or separating its own caloric; otherwise its temperature should correspond with that of the mother, which, we have seen, is not the fact.

That the *secretions* are actively exercised in the fœtus is proved by the circumstance, that all the surfaces are lubricated nearly as they are subsequently. The follicular secretion is abundant, and at times envelopes the body with a layer of sebaceous matter of considerable thickness. Vauquelin and Buniva have asserted, that this is a deposit from the abdomen of the liquor amnii; but, in reply to this, it may be urged, that we do not find it except on the body of the fœtus. It is not on the placenta or umbilical cord, and is most abundant on those parts of the fœtus, where the follicles are most numerous. The fat also exists in quantity after the fifth month. The greatest question has been with regard to the presence in the fœtal

state, of some of the secretions which are of an excrementitious character. For example, by some the *urinary secretion* is supposed to be in activity from the earliest period of uterine existence, and its product to be discharged into the liquor amnii. Such is the opinion of Meckel, but it does not rest on any basis of observation. The only circumstances, that in any manner favour it, are the fact of the existence of the kidneys at a very early period; and that at the full time, the bladder contains urine, which is evacuated soon after birth. On analysis, this is found to be less charged with urea and phosphoric salts than in after life.

Of the *meconium* we have already spoken. It is manifestly an excretory substance, produced, probably, by the digestion of the fluids of the alimentary canal, mixed with bile. Some, indeed, are of opinion, that it is altogether a secretion from the liver, and intended to purify the blood sent from the mother, so as to adapt it for the circulation of the fœtus. Into the value of the theory on which this notion rests, we have inquired at some length. The notion itself does not require farther examination. Vauquelin analyzed the meconium evacuated after birth, and found it composed of water, about two-thirds; of a substance of a vegetable nature, but *sui generis*, about one-third; mucus, a few hundredth parts, and a little bile. It appears, consequently, to be less azoted than the excrement of the adult.

Lastly, the *cutaneous perspiration* is supposed to be a fœtal excretion, and to be poured into the liquor amnii; but although this is probable, we have no positive evidence on the subject.

III. *Functions of Reproduction.*—These require no consideration. They are inactive during the fœtal state, except that the testicles and the mammæ appear respectively to secrete a fluid, which is neither sperm nor milk, and is found in the vesiculæ seminales in the one case, and in the lactiferous ducts in the other.

OF THE AGES.

Under this head we have to include the modifications that occur in the functions during the life of man, from birth until dissolution. The different ages may be separated as follows:—*Infancy*, comprising the period from birth till the second dentition;—*childhood*, that between the second dentition and puberty;—*adolescence*, that between puberty and manhood;—*virility*, that between youth and old age;—and *old age*.

Sect. I. *Infancy*.

The age of infancy extends from birth to the second dentition, or until about the seventh or eighth year. By Hallé, and after him by Renauldin, Rullier, Adelon, and others, this has been again subdivided into three periods, which are somewhat distinct from each other, and may therefore be adopted with advantage. The one comprises the period between birth and the first dentition,—generally about seven months; a second embraces the whole period of the first dentition, or up to about two years; and the third includes the whole interval, that separates the first from the second dentition.

1. *First period of Infancy.*—As soon as the child is ushered into the world, it assumes an independent existence, and a series of changes occurs in its functions of the most sudden and surprising character. Respiration becomes established, after the manner in which it is to be effected during the remainder of existence; and the whole of the peculiarities of fœtal circulation cease,—the organs of these peculiarities being modified in the manner to be described presently.

As soon as the child is extruded it begins to breathe, and at the same time to cry. What are the agencies, then, by which this first inspiration is effected, and this disagreeable impression is made upon the new being at the moment when it makes its appearance amongst us? This has been an interesting topic of inquiry amongst physiologists. A few of the hypotheses, that have been indulged, will be sufficient to exhibit the direction which the investigation has taken.

Whytt,—whose views were long popular, and still have supporters,—conceived, that, before birth, the blood of the fœtus is properly prepared by the mother; and that when, after birth, it no longer receives the necessary supply, an uneasy sensation is experienced in the chest, which may be looked upon as the appetite for breathing, in the same manner as hunger and thirst are appetites for meat and drink. To satisfy this appetite, the brain excites the expansion of the chest, to prevent the fatal effects that would ensue if the lungs

were not immediately aroused to action. This appetite is supposed to commence at birth, owing to the circulation being quickened by the struggles of the fœtus at that period, and to an additional quantity of blood passing through the lungs, which excites them to action, and seems to be the immediate cause of the appetite. Haller ascribed the first inspiration to the habit which the fœtus has acquired, whilst in the uterus, of taking into the mouth a portion of the liquor amnii; and he supposed that it still continues to open its mouth, after leaving the mother, in search of its accustomed food. The air, consequently, rushes into the lungs, and expands them; the blood is distributed through them, and a regular supply of fresh air is needed to prevent the blood from stagnating in its passage from the right to the left side of the heart. Dr. Wilson Philip regards the muscles of inspiration as entirely under the control of the will; and he thinks, that they are thrown into action by the uneasy sensation experienced by the new being, when separated from the mother, and having no longer the necessary changes produced upon the blood by her organs. Adelon thinks it probable, that the series of developements, occurring during gestation, predispose to the establishment of respiration. According to him, the lungs gradually increase in size during the latter months; the branches of the pulmonary vessels become enlarged, and the ductus arteriosus less; so that the lungs are prepared for the new function they have to execute. In addition to these alterations, he conceives, that the process of accouchement predisposes to the change; that, by the contractions of the uterus, the circulation of the blood must be necessarily modified in the placenta, and, consequently, in the fœtus,—for he is a believer in the doctrine, that the fœtus receives blood from the mother by the placenta. Owing to this disturbance in the circulation, more blood is sent into the lungs; and, when the child is born, it is subjected to new and probably painful impressions. "For instance," he remarks, "the external air, by its coldness and weight, must cause a disagreeable impression on the skin of the infant, as well as on the origin of all the mucous membranes; and, perhaps, the organs of the senses being, at the same time, suddenly subjected to the contact of their proper irritants, receive painful impressions from them. These different impressions being transmitted to the brain, they are reflected into the different dependencies of the nervous system, and, consequently, into the nerves of the inspiratory muscles: these muscles, thus excited, enter into contraction, in the same manner as the heart is stimulated to renew its contractions, during syncope, by inspiring a stimulating vapour."

None of these views satisfactorily explain the true physiology of the first inspiration; nor is it probable, that any can be devised which has not its difficulties. That, which has been embraced by Dr. Bostock and Sir Charles Bell, appears to us to be liable to fewer objections than any we have seen; and to explain the process, so far as is perhaps practicable, on mechanical principles.

The first respiratory act, according to them, seems to be purely mechanical, and to result from the change of position which the child undergoes at birth. From the mode in which it rests in utero, everything is done that position could accomplish, to diminish the dimensions of the chest; and any change in this position must have the effect of liberating the lungs from a portion of the pressure which they sustain. The head cannot be raised from the breast, nor the knees removed from the abdomen, without straightening the spine, and the spine cannot be reduced to a straight line without elevating the ribs, and permitting the abdominal viscera to fall; but the ribs cannot rise, nor the diaphragm descend, without enlarging the chest; and, as the chest enlarges, the lungs, which are the most elastic organs of the body, expand their air-cells, hitherto collapsed by external pressure, and the external air rushes in. The same cause is considered to account for the new circulatory movement. The blood, which, in the fœtus, had passed through the foramen ovale and the ductus arteriosus without visiting the lungs, is solicited from its course by the expansion of the chest, which draws the blood through the pulmonary artery as forcibly as it does air through the windpipe. The blood, thus exposed to the air in the lungs, becomes arterialized, and, from this moment, the distinction between arterial and venous blood is established. The circulation, through the vessels peculiar to the fœtal condition, now ceases, even without any ligature being placed upon the umbilical cord.

The sudden and important changes supervening in this manner guide us to the decision of an interesting medico-legal inquiry,—viz. whether, in a case of alleged infanticide, the child has respired or not;—in other words, whether it has been born alive or dead?

After respiration has been established, the lungs, from being dark-coloured and dense, become of a florid red hue; are light and spongy, and float on water; on cutting into them, the escape of the air in the air-cells occasions a crepitus, and a bloody fluid exudes; there is an approach to closure of the foramen ovale; the ductus arteriosus is empty, as well as the ductus venosus; and the absolute weight of the lungs may be doubled.

Respiration having been once thoroughly established, the individual enters upon the period of infancy, which has now to engage our attention.

The animal functions, during this period, undergo considerable developement. The sense of tact is little evinced, but it exists, as the child appears sensible to external cold. At first, the touch is not exerted under the influence of volition, but, towards the termination of the period, it begins to be active. The taste is almost always null at first. Adelon thinks, that it is probably exerted on the first day as regards the fluids, which the infant sucks and drinks. We have daily evidence, however, that at an early period of existence, the most nauseous substances, provided they are not irritating, will be swallowed indiscriminately, and without the slightest repug-

nance; but, before the termination of the period, we are considering, the taste becomes inconveniently acute, so that the exhibition of nauseous substances, as of medicine, is a matter of more difficulty. The smell is probably more backward than any of the other senses; the developement of its organ being more tardy, the nose being small, and the nasal sinuses not in existence. In the first few weeks, sight and hearing are imperfectly exerted, but, subsequently, they are in full activity. The internal sensations, being instinctive, exist; all those at least that are connected with the animal and nutritive functions. Hunger and thirst appear during the first day of existence; the desire of passing the urine and fæces is doubtless present, notwithstanding they appear to be discharged involuntarily; and the morbid sensation of pain is often experienced, especially in the intestinal canal, owing to flatus, acidity, &c. During the first part of the period, the child exhibits no mental and moral manifestations; but, in the course of a few weeks, it begins to notice surrounding objects, especially such as are brilliant, and to distinguish between the faces to which it has been accustomed and those of strangers; awarding the smile of recognition or of satisfaction to the former, the look of gravity and doubt to the latter. Locomotion is, at this time, utterly impracticable, as well as the erect attitude. The muscular system of the child is not yet sufficiently developed; the spinous processes of the vertebra are not formed, and it has not learned to keep the centre of gravity—or rather the vertical line—within the base of sustentation. The function of expression is at the early part of the period confined to the *vagitus* or squalling, which indicates the existence of uneasiness of some kind; but, before the termination of the period, it unites smiles and even laughter to the opposite expressions, and will attempt to utter sounds, which cannot yet be considered as any attempt at conventional language. Sleep is largely indulged. Soon after birth, it is almost constant, except when the child is taking nutriment. Gradually, the waking intervals are lengthened; but, throughout, much sleep is needed, owing to the frail condition of the nervous system, which is soon exhausted by exertion however feeble, and requires intermission of action.

After birth, the child has to subsist upon a different aliment from that with which it was supplied whilst in the maternal womb. Its digestion, therefore, undergoes modification. The nutriment is now the milk of the parent, or some analogous liquid, which is sucked in, in the manner described under the head of *Digestion*. For this kind of prehension, the mouth of the infant is well adapted. The tongue is very large, compared with the size of the body, and the want of teeth enables the lips to be extended forward, and to embrace the nipple more accurately and conveniently. The action of sucking is doubtl ss as instinctive as the appetite for nutriment, and equally incapable of explanation. The appetite appears to be almost incessant, partly owing to the rapidity of the growth, demanding continual supplies of nutriment, and partly, perhaps, owing to a

feeling of pleasure experienced in the act, which is generally the prelude to a recurrence of sleep, broken in upon, apparently, for the mere purpose of supplying the wants of the system, or the artificial desire produced by frequent indulgence. Often, we have the strongest reason for believing, that the great frequency of the calls of the appetite is occasioned by the habit, with many mothers, of putting the child constantly to the breast; whilst in those children that have been trained, from the earliest period of existence, to receive the nutriment at fixed hours only, the desire will not recur until the lapse of the accustomed interval.

Digestion is, at this age, speedily accomplished; the evacuations being frequent,—two or three or more in the course of the day,—of a yellow colour, something like custard, or curdy, and having by no means the offensive smell, which they subsequently possess. During the first days after birth, they are dark and adhesive, and consist of the *meconium*, already described. Young mothers are apt to be alarmed at this appearance, which is entirely physiological, and always exists. The respiration of the infant is more frequent than in the adult, nearly in the proportion of two to one, and it is chiefly accomplished by the muscles that raise the ribs, on account of the great size of some of the abdominal viscera, which do not permit the diaphragm to be readily depressed. The stethoscope exhibits the respiration to be much more sonorous; so characteristic, indeed, is it, in this respect, that it has been called "puerile," by way of distinction. It appears to indicate a greater degree of dilatation of the bronchial ramifications, and, consequently, a greater admission of air than occurs in after life. The circulation is more rapid; the pulsations at birth being nearly twice as numerous as in the adult. Nutrition is very active in the developement of the different organs. Calorification becomes gradually more energetic from the time of birth. The recrementitial secretions, as well as the excrementitial, are as regularly formed as in the adult; but the products vary somewhat. The urine, for instance, is less charged with urea, and contains benzoic acid; the perspiration is acidulous, &c. &c.

Adelon asserts, that these excretions are frequently insufficient for the necessary depuration, and that nature, therefore, establishes others that are irregular and morbid, in the shape of cutaneous efflorescences, &c. These can scarcely be regarded as depurations, unless we consider all cutaneous eruptions, that are connected with gastric or digestive irritation, to be thus induced, which is more than problematical; especially as most of them are neither pustular nor vesicular, and therefore, not accompanied by any sensible exudation.

2. *Second period of infancy*, or *first dentition*.—This period embraces the whole time of dentition, and is considered to include the age between seven months and two years. In it, the external senses are in great activity, and continually furnishing to the intel-

lect the means for its developement, connected with the universe. The internal sensations are likewise active. From these united causes, as well as from the improved cerebral organization, the intellect is more strengthened during this period than perhaps during any other. The senses are continually conveying information; perception is, therefore, most active, as well as memory; whilst imagination and judgment are feeble and circumscribed. The faculty of imitation is strong, so that, by hearing the spoken language, and appreciating its utility, the child endeavours to produce similar sounds with its own larynx, and gradually succeeds,—the greater part of its first language consisting of imitations of sounds emitted by objects, which sounds are applied to designate the object itself, in the manner we have seen elsewhere. The affective faculties are likewise unfolded during this period, but generally those of the selfish cast are predominant, and require the most careful attention for their rectification. Even at this early time of life, the effect of a well-adapted education is striking, and spares the child from numerous inconveniences, to which unlicensed indulgence in its natural passions would inevitably expose it. The general feeling is, that the infant is not yet possessed of the necessary intelligence to pursue the course that is indicated; but it is surprising how soon it may be made to understand the wishes of its instructor, and with what facility it may be moulded, at this tender age, in almost any manner that may be desired. During this period, the child is capable of standing erect and of walking. Previous to this, these actions were impracticable, for the reasons already stated, as well as owing to the weight of the thoracic and abdominal viscera,—to the spine having but one curvature, the convexity of which is backwards,—to the smallness of the pelvis, and its inclination forwards, so that it scarcely supports the weight of the abdominal viscera,—and to the smallness of the lower limbs and the feebleness of their muscles, which are insufficient to prevent the trunk from falling forward.

These imperfections are, however, gradually obviated, and the child commences to support itself on all-fours; a position assumed much more easily than the biped attitude, owing to the centre of gravity being situated low, and the base of sustentation being large. In this attitude, he moves about for some time, or his locomotion is effected by pushing a chair before him, or by being steadied by his nurse. Gradually, he passes from place to place on his feet, by laying hold of surrounding objects, and, in proportion as the bones and muscles become developed, and the obstacles to progression are removed, he succeeds in walking alone; but it is some time before he is capable of running or leaping. Perhaps, the average period, at which the infant begins to walk, is about twelve months; but we see great difference in this respect.

When once the infant is fairly on his legs, the whole of his waking hours is spent in incessant activity and amusement. His functions

of expression are commensurate with his intellectual developement, which we have seen to be great in this period. Sleep, which is now more interrupted, is still imperiously and frequently demanded, the nervous system being devoid of that strength, which it subsequently possesses, and therefore requiring repose.

One of the most important changes going on at this age concerns the function of digestion. This is the process of *dentition*, which usually commences about the seventh month, and continues till the end of the second year at least. Prior to the appearance of the teeth, mastication is of course impracticable; and the food, best adapted for the delicate powers of the infant, is that afforded by the maternal breast, or a substitute which resembles it as closely as possible. The appearance, however, of teeth would seem to indicate, that the infant is about to be adapted for more solid aliment. As early as the second month of utero-gestation, if the jaws be carefully examined, the germs of the teeth are perceptible in their substance, under the form of membranous follicles of an oval shape, attached by their deep-seated extremity to a vascular and nervous pedicle, and by their superficial extremity to the gum. The cavity of these follicles, according to Béclard, is at first filled with a colourless, limpid fluid; but a kind of vascular and nervous papilla or pulp soon forms in it, which commences at the deep-seated portion of the follicle, proceeds towards the other extremity, and ultimately fills it,—the fluid diminishing in proportion to the increase of the pulp. About the termination of the third month, ossification begins, and a little sooner in the lower than in the upper jaw. This consists, at first, in a deposition of ivory matter on the surface of the pulp and at its top, which goes on increasing in width until it covers the whole of the dental pulp with a shell of bone. It augments, also, in thickness at the expense of the dental pulp, which becomes gradually less and less. When the bony shell has extended as far as the neck of the tooth, the external membrane or sac of the tooth—for the follicle consists of two membranes—attaches itself closely, but not by adhesion, to the part. The inner membrane becomes much more vascular, and the *enamel* is secreted by it. A thickish fluid is observed to be poured out from the inner surface, which is soon consolidated into a dark, chalky substance, and afterwards becomes white and hard.

At birth, the coronæ of the incisors are formed; those of the canine are not completed; whilst the molares have only their tubercles. The root or fang is formed last of all. As ossification proceeds, the corona of the tooth presses upon the gum, a portion of the follicle being interposed, which is gradually absorbed as well as the gum, and the tooth issues.

The age, at which the teeth make their appearance, varies. Occasionally, children have been born with them, whilst in other cases they have not pierced the gum until after the period we are considering. Generally, the middle incisors of the lower jaw appear

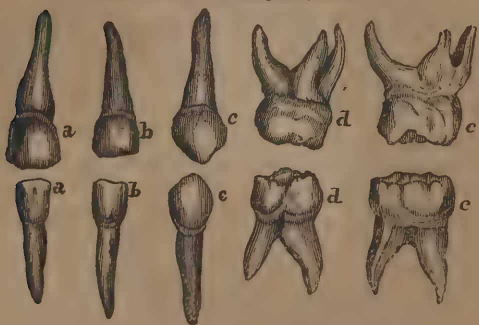
about the seventh month, and, subsequently, those of the upper jaw; next the inferior and superior lateral incisors in succession; then the first lower molares, and the first upper; next the inferior and superior canine teeth, successively; and, lastly, the second molares of each jaw.

The approximate times of their appearance are thus estimated by Mr. Thomas Bell.

From five to eight months, the four central incisors.
From seven to ten, the four lateral incisors.
From twelve to sixteen, the four anterior molares.
From fourteen to twenty, the four canine.
From eighteen to thirty-six, the four posterior molares.

Fig. 185.

1. Front view of the temporary teeth.



2. The separate temporary teeth of each jaw.

a. The central incisor.—*b.* The lateral incisor.—*c.* The canine.—*d.* The first molaris.—*e.* The second molaris.

Dentition is necessarily a physiological process, but it is apt to be a cause of numerous diseases. The whole period of its continuance is one of great nervous susceptibility,—so that the surgeon never operates during it, unless compelled,—and we can understand, that the pressure, exerted by the tooth on the gum, and the consequent

inflammation and irritation, may lay the foundation for numerous diseases. More are doubtless ascribed to the process than it is entitled to, but still they are sufficiently numerous; and all require, in their management, the free division of the distended gum, so as to set the presenting part of the tooth at liberty.

Whilst the teeth are appearing, the muscular structure of the body generally is acquiring strength, and the salivary organs are described by anatomists as becoming much more developed. The food of the child is now diversified, and it begins to participate in the ordinary diet of the table. The excrementitious matters are consequently altered in their character, particularly the alvine, which become firmer, and acquire the ordinary fæcal smell; the urea is still, however, in the generality of cases, in less proportion than in the adult. The other functions require no particular mention.

The mortality, during this period, is great. The bills of mortality of London, as has been elsewhere remarked, show, that the deaths, under two years of age, are nearly thirty per cent. of the whole number. In Philadelphia, during a period of twenty years ending with 1826, the proportion was rather less than a third. The cholera of infants is the great scourge of our cities during the summer months, whilst in country situations it is comparatively rare; and it is always found to prevail most in crowded alleys, and in the filthiest and impurest habitations. There is something in the confined and deteriorated atmosphere of a town, which seems to act in a manner directly unfavourable to human life, and to the life of the young especially. This is not confined to man. It is applicable also to the animal. Experiments were instituted by Jenner, and since him by Dr. Baron, which show that a privation of free air and of their natural nourishment has a tendency to produce disorganization and death. Dr. Baron placed a family of young rabbits in a confined situation, and fed them with coarse green food, such as cabbage and grass. They were perfectly healthy when put up. In about a month, one of them died,—the primary step of disorganization being evinced by a number of transparent vesicles on the external surface of the liver. In another, which died nine days after, the disease had advanced to the formation of tubercles in the liver. The liver of a third, which died four days later, had nearly lost its true structure, so completely was it pervaded by tubercles. Two days afterwards, a fourth died: a number of hydatids was attached to the lower surface of the liver. At this time, Dr. Baron removed three young rabbits, from the place where their companions had died, to another situation, dry and clean, and to their proper accustomed food. The lives of these were obviously saved by the change. He obtained similar results from experiments of the same nature performed on other animals.

3. *Third period of infancy.*—This requires no distinct consideration;—the growth of the child and the activity of the functions going on as in the preceding period, but gradually acquiring more and more energy. Within this period, a third molar tooth appears, which is not, however, temporary, but belongs to the permanent set.

During the whole of infancy, the dermoid texture—both skin and mucous membranes—is extremely liable to be morbidly affected; hence, the frequency of eruptive diseases, and of diarrhœa, aphthæ, croup, bronchitis, &c., many of which are of very fatal tendency. Owing, also, to the susceptibility of the nervous system, convulsions, hydrocephalus, and other head affections are by no means infrequent.

Sect. II.—*Childhood.*

Childhood may be considered to extend from the seventh to the fifteenth year, or to the period of puberty; and it is particularly marked by the *shedding* of the first set of teeth, and the appearance of the second. It is manifest, that in the growth of the jaws with the rest of the body, the teeth, which, for a time, may have been sufficient in magnitude and number, must soon cease to be so; hence, the necessity of a fresh set, which may remain permanently. The process for the formation of the permanent teeth is similar to that of the milk or temporary teeth; yet it presents some remarkable points of difference; and it affords us another surprising instance of the wonderful adaptation of means to definite objects, of which we have so many in the human body.

This process has been well described by Mr. Thomas Bell,—in his recent work on the "Anatomy, Physiology, and Diseases of the Teeth,"—an individual whose opportunities for observation have been unusually numerous, and whose zeal and ability in his profession, as well as in the prosecution of natural science, are well known.

The rudiments of the permanent teeth are not original, and independent, like those of the temporary. They are derived from the latter, and continue, for a considerable time, attached to, and intimately connected with, them.

At an early period in the formation of the temporary teeth, the investing sac gives off a small process or bud, containing a portion of the essential rudiments, namely, the pulp, covered by its proper membrane. This constitutes the rudiment of the permanent tooth. It commences in a small thickening on one side of the parent sac, which gradually becomes more and more circumscribed, and, at length assumes a distinct form, though still connected with it by a pedicle. For a time, the new rudiment is contained within the same alveolus as its generator, which is excavated by the absorbents for its reception. It is not, according to Mr. Bell, in consequence of the pressure of the new rudiment upon the bone, that this absorption is

Fig. 186.

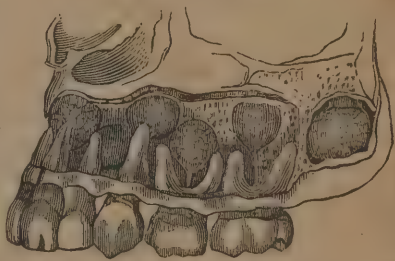
a.—Permanent rudiment given off from the temporary in an incisor.
b.—Permanent rudiment given off from the temporary in a molaris.

occasioned, but by a true process of anticipation; for he states, that he has seen, in the human subject—and still more evidently in the foal—the commencement of the excavation before the new sac was formed, and, consequently, before any pressure could have taken place on the parietes of the socket. The absorption does not, indeed, begin in the smooth surface of the socket, but in the cancelli of bone immediately behind it. By degrees, a small recess is thus formed in the paries of the alveolus, in which the new rudiment is lodged, and this excavation continues to increase with the increasing size of the rudiment; whilst, at the same time, the maxillary bone becomes enlarged, and the temporary tooth, advancing in its formation, rises in the socket. The new cell is thus gradually separated from the other, both by being itself more and more deeply excavated in the substance of the bone, and also by the formation of a bony partition between them, as seen in the marginal figure, 187, which exhibits the connexion between the temporary tooth and the permanent rudiment, as it exists after the former has passed through the gum. As the temporary tooth grows and rises in the jaw, the connecting cord or pedicle elongates, and although the sac, from which it is derived, is gradually absorbed, it still remains attached to the neck of the temporary tooth. The situation of each permanent rudiment, when its corresponding temporary tooth has made its appearance through the gum, is deeper in the jaw and a little behind the latter, as represented in the marginal illustrations, Fig. 188 & 189, of the upper and lower jaw after the whole of the temporary teeth have passed through the gum. From these, it will be understood, how the upper part of the sac of the permanent rudiment, being, by means of the cord, connected with the gum, gradually assumes the same relation to the gum as was originally sustained by the temporary rudiment.

Fig. 187.

Temporary tooth and permanent rudiment.

Fig. 188.



Temporary teeth and permanent rudiments.

Fig. 189.

Temporary teeth and permanent rudiments.

The ossification of the permanent teeth commences from the third to the sixth month after birth,—for the incisors and first molaris; about the ninth month, for the canine teeth; about three

years, for the second molaris; at three years and a half, for the fourth; and, at ten years, for the fifth; but all this is liable to much variation.

The permanent teeth, during their formation, are crowded together in the jaw; but, as soon as they have advanced to a certain point, and can no longer be contained within their own alveoli, absorption of the anterior parietes of those cavities takes place, and the teeth are allowed to come in some measure forwards. In consequence of such absorption, it frequently happens, that not only the socket of the corresponding temporary tooth, but that of the tooth on each side is opened to the permanent one. Absorption now occurs in the root of the temporary tooth,—generally at the part nearest its successor, and this gradually proceeds as the latter advances, until the root is completely removed, when the crown falls off, leaving room for the permanent tooth to supply its place. It does not seem, that this absorption of the root is produced by pressure on the part of the permanent tooth, as it often happens, according to Mr. Bell, that the root of the temporary tooth is wholly absorbed, and the crown falls out spontaneously, long before the succeeding tooth has approached the vacant space. As a general rule, however, the actions must be regarded consentaneous; and Mr. Bell thinks, that this absorption resembles that, already referred to, for the formation of a new cell to receive the permanent pulp, and that it may be termed, like it, a "process of anticipation." In both instances, the existence, though not the pressure, or even the contact, of the new body is necessary to excite the action of the absorbent vessels; and we, accordingly, find, that in those cases, by no means unfrequent, in which the temporary teeth retain their situation in the mouth, with considerable firmness, until adult age, the corresponding permanent ones have not been formed.

The following are the periods at which the permanent teeth generally make their appearance. They are extremely irregular, however, in this respect: the estimate must, consequently, be regarded as a general approximation only.

Anterior or first great molares, - - -	$6\frac{1}{2}$ years.
Middle incisors, - - - - -	7
Lateral incisors, - - - - -	8
Anterior bicuspids, or first lesser molares, -	9
Posterior bicuspids, or second lesser molares,	10
Canine teeth, - - - - - - -	11 or 12
Second great molares, - - - -	12 or 13
Third great molares or *dentes sapientiæ*, -	17 to 20

When these have all appeared, the set is complete, consisting of thirty-two teeth, sixteen in each jaw,—the number of temporary teeth having been only twenty. The accompanying figure represents the upper and lower permanent teeth in their alveoli or sockets, the external alveolar plate having been removed to show the mode in which they are articulated. Fig. 191 represents the same teeth when removed from the socket.

Fig. 190.

Upper and lower teeth of the left side of the jaws.

While the jaws are becoming furnished with teeth and increasing in size, they undergo a change of form, and the branches become

Fig. 191.

Upper and lower teeth,

a, a. Central incisors.—*b, b.* Lateral incisors.—*c, c.* Canine teeth.—*d, d.* First bicuspidati.—*e, e.* Second bicuspidati.—*f, f.* First molares.—*g, g.* Second molares.—*h, h.* Third molares or *dentes sapientiæ.*

more vertical, so as to favour the exertion of force during mastication. When the teeth issue from the gums, they are most favourably situated for the act of mastication; the incisors are sharp, the canine pointed, and the molares studded with conical asperities; but, in the progress of age, they become worn on the surfaces, which come in constant contact.

During the occurrence of these changes, which embrace the whole of the period we are considering, and extend, at times, into the two next, the animal functions, especially that of sensibility, become surprisingly developed, and the intellectual and moral results of a well adapted system of education are strikingly apparent. The nutritive functions are, likewise, performed with energy, the body not yet having attained its full growth; and, towards the end of the period, the organs of reproduction commence that developement, which we have to describe under the next period.

Sect. III. *Adolescence.*

The commencement of this age is marked by one of the most extraordinary developements, which the frame experiences, and its termination by the attainment of full growth in the longitudinal direction. The period of the former of these changes is termed *puberty;* that of the latter the *adult age.*

The age of adolescence has been considered to extend from fifteen years to twenty-five, in men; and from fifteen to twenty-one, in women; but this is only an approximation, like the other divisions of the ages, all of which are subject to great fluctuations in individual cases.

During the periods we have considered, no striking difference exists between the appearance of the male and female, except as regards the generative organs; but, about the age of puberty, essential changes occur, that modify the characteristics of the two sexes in a manner, which they maintain through the remainder of existence; and these changes affect the whole of the economy to a greater or less degree.

In the male, the skin loses more or less of its delicacy and whiteness; the hair becomes darker, the cellular tissue condensed, and the muscles more bulky, so that they are strongly marked beneath the surface; the beard appears, as well as hair upon the pubes, chest, and in the axillæ. The different parts of the body become developed in such manner that the centre of the frame now falls about the pubes. The encephalon has increased in size, especially at the posterior and inferior part—the cerebellum—and has become firmer. The ossification of the bones, in the direction of their length, terminates towards the end of the period. The muscles become more red and fibrinous, losing the gelatinous character they previously possessed, and, in the animal, exhibiting those striking changes which we see—from veal to beef, from lamb to mutton, &c. The larynx undergoes

great augmentation, and the glottis particularly is elongated and widened. The jaws complete their growth, and the dentes sapientiæ appear, so as to make up the full complement of sixteen teeth in each jaw. The changes in the nutritive organs are not great, consisting chiefly in their developement to correspond with the increased size of the frame. The greatest modification is produced in the organs of reproduction, which are now in a state to exercise their important functions. The testicles, at the period of puberty, suddenly enlarge so as to attain twice the diameter they previously possessed; and the secretion of sperm is accomplished. The penis is also greatly increased in size; and, according to Adelon, "becomes susceptible of erection." This susceptibility, however, exists long before this age. It may be noticed even in the first period of infancy. The scrotum assumes a deeper colour.—Such are the chief changes that supervene in the male.

In the female, they are not quite so striking;—the general habit remaining much the same as during childhood. The skin preserves its primitive whiteness; and, instead of the cellular tissue becoming more condensed, and the muscles more marked, as in the male, fat is deposited in greater quantity between the muscles, so that the form becomes more rotund. New hair appears only on the organs of reproduction and in the axillæ, whilst that of the head begins to grow more rapidly. The developement of the genital organs is as signal as in the male. The ovaries attain double their previous dimensions; the uterus enlarges; and a secretion takes place from it which has been elsewhere described—the *menstrual flux;* the mons veneris and labia pudendi are covered with hair; the labia enlarge, and the pelvis has its dimensions so modified as to render labour practicable. At an early age, the long diameter of the brim is from before to behind; but it now assumes the opposite direction, or from side to side; and the bosom, which, prior to this age, could scarcely be distinguished from that of the male, becomes greatly augmented; fat is deposited so as to give the mammæ their rotundity; the mammary gland is enlarged; and the nipple of greater size;—changes fitting the female for the new duties, which she may be called on to exercise.

The functions undergo equally remarkable modifications, under the new and instinctive impulse, which animates every part of animal life. The external senses attain fresh, and peculiar activity; the intellectual faculties become greatly developed, and this is the period, during which the mental character is more modified and improved by education than any other. It embraces the whole time of scholastic application to the higher studies: prior to the end of the period, the male youth enters upon the avocation which is to be his future support, and both sexes may become established in life in the new relations of husband and wife, and of parent and child. It is during this age, that the indescribable feeling of interest and affection is experienced between individuals of the two sexes;

and that the boldness of the male contrasts so strikingly with the captivating modesty of the tender female;—

> "That chastity of look, which seems to hang,
> A veil of purest light o'er all her beauties."

The muscles, having acquired their strength and spring, the severer exercises are now indulged, and mechanical pursuits of all kinds,—military or civil,—are undertaken with full effect. The expressions participate in the altered condition of the mental and moral manifestations, and indicate vivacity, energy, and enthusiasm. The voice of the male acquires a new character, and becomes graver, for reasons assigned elsewhere; whilst that of the female experiences but slight modification.

The nutritive functions of digestion, absorption and respiration experience but little change; but nutrition, strictly so called, is evidently modified, from the difference, which we notice in the developement and structure of the various organs. The muscles contain more fibrine; the blood is thicker and richer in globules; and the excretions manifest a higher degree of animalization. Urea has usurped the place of benzoic acid in the urine; and the cutaneous transpiration has lost its acidulous smell, and become rank and peculiar.

Lastly, the sexual functions are now capable of full and active exercise, and appear to be intimately connected with the energy and developement of many parts of the economy. If the genital organs do not undergo the due change at puberty, or if the testes of the male or the ovaries of the female be removed prior to this age, considerable modification occurs. This is more manifest in the male, inasmuch as the ordinary changes, that supervene at puberty, are in him more marked than in the female.

The removal of the testicles, prior to puberty, arrests those changes. The beard does not appear, nor the hair in the axillæ or on the pubes, as in the entire male; and if those animals, in which the males are distinguished by deciduous horns, as the stag,—or by crests and spurs, as the cock, be castrated before their appearance, such appendages never present themselves. If, however, they be castrated after puberty, they retain these evidences of masculine character. The eunuch, likewise, who becomes such after the appearance of the beard, preserves it, although to a less extent than usual.

The developement of the larynx is arrested by castration, so that the voice retains, with more or less change, the treble of the period prior to puberty; and hence this revolting operation has been had recourse to for the sake of gratifying the lovers of music.

In the progress of age, we find that, during the progressive evolution of the organs, one set will be liable to morbid affections at one period, and another set at another. In the early ages, the

mucous membranes and the head are peculiarly liable to disease; and, at the period we are now considering, affections of the respiratory organs become more prevalent. It is, indeed, the great age for pulmonary consumption,—that fatal malady, which, it was supposed by Sydenham, destroys two-ninths of mankind. In the female, whose proper feminine functions do not appear at the due time, or are irregularly exercised, the commencement,—and indeed the whole of this period,—is apt to be passed in more or less sickness and suffering.

Sect. IV. *Virility or Manhood.*

Hallé has divided this age into three periods,—*crescent, confirmed*, and *decrescent virility*. The *first* of these extends from the age of twenty-five to that of thirty-five in the male, and from twenty-one to thirty in the female; the *second* from thirty-five to forty-five in the male, and from thirty to forty in the female. Neither of these will require remark, the whole of the functions throughout this work,—when not otherwise specified,—being described as they are accomplished in manhood. Owing to the particular evolution of organs, however, the tendency is not now so great to morbid affections of the respiratory function. It is more especially the age for cephalic and abdominal hemorrhage; accordingly, apoplexy and hemorrhoidal affections are more frequent than at any previous period.

In *decrescent virility*,—in which Hallé comprises the period of life between forty and fifty in the female, and between forty-five and sixty in the male,—signs of decline are manifest. The skin becomes shriveled and wrinkled; the hair is gray, or white and scanty; the teeth are worn at the top, chipped, loose, and many—perhaps—lost. The external senses, especially the sight, are more obtuse, partly owing to a change in the physical portions of the organ, so that powerful spectacles become necessary, and partly owing to blunted nervous sensibility. Owing to the same cause, the intellectual faculties are exerted with less energy and effect, and the moral manifestations are more feeble and less excitable.

Locomotion is less active, owing to diminution in the nervous power, as well as probably to physical changes in the muscles, so that the individual begins to stoop,—the tendency of the body to bear forwards being too great for the extensor muscles of the back to counteract. The expressions participate in the condition of the intellectual and moral acts, and are, consequently, less exerted than in former periods.

The nutritive functions do not exhibit any very remarkable change, and will even remain active until a good old age.

The functions of reproduction show the greatest declension, especially in the female. The male may preserve his procreative capabilities much longer than this period, but in the female the power is,

usually, entirely lost, the loss being indicated by the cessation of menstruation. After this, the ovaries shrivel, the uterus diminishes in size, the breasts wither, the skin becomes brown and thick, long hairs appear on the upper lip and chin, and all those feminine points are lost, which were previously so attractive. The period of the cessation of the menses is liable to many different disorders, which are the source of much annoyance, and are, at times, attended with fatal consequences. Prior to their total disappearance, they become extremely irregular in their recurrence, sometimes returning every fortnight, debilitating by their frequency, and by the quantity of the fluid lost, and laying the foundation, in many cases, for uterine or other diseases of a serious character. Cancerous affections of the mammæ or labia, which had been previously dormant or not in existence, now arise or become developed, and at times with extreme rapidity. In consequence of the great liability to such affections, this has been called the *critical age*, *critical period*, or *critical time of life*, or *turn of life*. The danger to the female is not, however, so "critical" at this period as the epithet might suggest,—the statistical researches of De Chateauneuf and Lachaise and others having shown, that between the ages of 40 and 50 no more women die than men.

Sect. V. *Of Old Age.*

This is the age when everything retrogrades. It is the prelude to the total cessation of the functions, where the individual expires,—which is but rarely the case,—from pure old age.

This period, again, has been divided into three stages:—*incipient* or *green old age*, reaching to seventy years; *confirmed old age* or *caducity*, to eighty-five years; and *decrepitude*, from eighty-five years upwards.

In *incipient* or *green old age*, the declension, which had occurred in the period of *decrescent virility*, is now more marked. The intellectual and moral manifestations exhibit more marked signs of feebleness; the muscular powers totter, and require the aid of a support,—as well to convey a part of the weight of the body to the ground, as to enlarge the base of sustentation. The muscles of the larynx participate in this general vacillation; the

> "Big manly voice,
> Turning again toward childish treble, pipes
> And whistles in his sound,"

and is broken and tremulous.

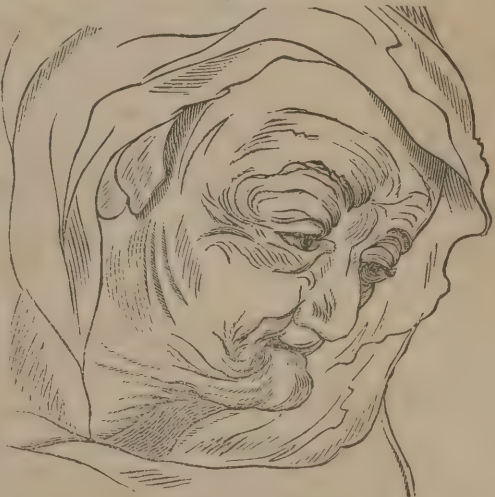
The appetite is great, and the powers of digestion considerable, but mastication is largely deteriorated. In the first place, the teeth fall out, in consequence of the constant deposition of fresh layers in the dental cavities, which ultimately close them, and obliterate the vessels, that pass to the internal papillæ for their nutrition. As soon

as the teeth have fallen out, the alveolar processes, which supported them, waste away by absorption, and the depth of the jaw is thus greatly lessened. On these accounts, the jaws only approach each other at the forepart; the chin projects, and the angle of the jaw is thrown more forward. As the teeth and the sockets disappear, the alveolar margins become thin and sharp, and the gum hardens over them; the chin and nose necessarily approach; (Fig. 193,) the lips fall in, and the speech is inarticulate. We can thus understand the peculiarities of the mastication of the aged. They are compelled to bite with the anterior portions of the jaws; for this reason, as well as owing to the greater obliquity of the insertion of the levator muscles of the lower jaw, but little force can be exerted; and, owing to the too great size of the lips, the saliva cannot be retained. Respiration is not as readily accomplished, partly owing to the complete ossification of the cartilages of the ribs, but chiefly to diminished muscular powers. The valves of the heart and many of the blood-vessels, especially of the extremities, become more or less ossified, and the pulse is slow and intermittent. Nutrition is effected to such a degree only as to keep the machine in feeble action; and animal heat is formed to an inadequate extent, so that the individual requires the aid of greater extraneous warmth. In many cases, the powers of reproduction in the male are completely lost.

Fig. 192.

Skull of the aged.

Fig. 193.



Physiognomy of the aged.

In *confirmed old age*, the debility of the various functions goes on augmenting. The mental and corporeal powers almost totter to their fall, and often a complete state of dementia or dotage exists. Frequently, however, we are gratified to find full intellectual and moral enjoyment prevailing even after this period, with the possession of considerable corporeal energy. The author has had the honour to enjoy the friendship of two illustrious individuals of this country, who have filled the highest office in the gift of a free people, one of whom is now no more, but the other he trusts destined to live for many years to come: both enjoyed, after the lapse of eighty-two summers, the same commanding intellectual powers and the same benevolence that ever distinguished them.

In this stage, locomotion becomes more difficult; the appetite is considerable, and the quantity eaten at times prodigious, the digestive powers being incapable of separating the due amount of chyle from the quantity of aliment, which was sufficient in the previous ages. Difficulty, however, sometimes arises in defecation, the muscular powers being insufficient to expel the excrement. From this cause, accumulations occasionally take place in the rectum, which may require the use of mechanical means, as injections, the introduction of an instrument to break them down, &c. Generation is, usually, entirely impracticable, erection being impossible; and, during the whole of this and the next stage, the urinary organs are liable to disorder,—irritability about the neck of the bladder, and incontinence of urine, being frequent sources of annoyance.

Finally, to this stage succeeds that of *decrepitude*, so well described by Shakespeare:—

> "Last scene of all,
> That ends this strange, eventful history,
> Is second childishness, and mere oblivion;
> Sans teeth, sans eyes, sans taste, sans everything."

The loss of power, mental and corporeal, becomes progressively greater; and, in addition to the abolition of most of the external senses—especially those of sight and audition—the intellectual faculties are, perhaps, entirely gone; all muscular motion is lost, and paralysis requires constant confinement to the bed, or to the easy chair; the excretions are passed involuntarily; sensibility becomes gradually extinct, and life finally flits away as imperceptibly as the twilight merges in the shades of night.

Such is a brief description of the chief changes, that befall the body in the different ages. To depict them more at length would be inconsistent with the object and limits of this elementary work. It is clear, that, although the divisions, which we have adopted from Hallé, are entirely arbitrary, must run into each other, and be liable to numerous exceptions;—certain well-marked changes occur about the commencement or termination of many of them, and singular

diversity takes place in the successive evolutions of organs; whilst some are predominant at one time, they fall behind others at a previous or subsequent period; and such changes may lay the foundation for morbid affections, at one age in certain organs, which do not prevail at another. The ancients, who believed that great mutations occur at particular intervals,—every three, seven or nine years, for example, as the particular number might be at the moment in favour,—compared these periods to knots uniting the different stages of life, and giving the economy a new direction. These knots they called the *climateric* or *climacteric years*, and they conceived the body to be especially liable to disease at the periods of their occurrence. The majority assigned them to the number seven and its multiples; and the fourteenth and twenty-first years especially were conceived to be replete with danger. Others applied the term *climacteric* to years resulting from the multiplication of seven with an odd number, and especially with nine: the sixty-third year being regarded, by almost all, as the *grand climacteric*. The error, with the ancients, lay, in considering that the numbers exerted any agency. Every one admits the influence of particular evolutions on health; and, at the present day, the word *climacteric* is generally restricted to certain periods of life, at which great changes supervene, independently of any numerical estimate of years;—such as the period of puberty in both sexes; that of the cessation of the menses, or the critical time of life in the female, &c.

Lastly, it need hardly be remarked, that the different ages we have described, instead of extending through the protracted period of eighty-five years and upwards, may be varied by original constitution, climate, habits of life, &c. so that the stages may be shorter than usual, and all the signs of decrepitude occur many years earlier; and, on the other hand, the period of decrepitude may, through strength of original conformation, and other causes, be largely postponed.

OF SLEEP.

The difference between the two classes of animal and nutritive functions is strikingly exhibited in the phenomena we have now to consider. Whilst the former are more or less suspended, the latter continue their action with but little modification.

The functions of sensibility, voluntary motion, and expression, cannot be indulged for any length of time, without fatigue being induced, and a necessity arising for the reparation of the nervous energy, which has been expended during their action. After a time,—the length of which is somewhat influenced by habit,—the muscles have no longer power to contract, or the external senses to receive impressions; the brain ceases to appreciate; mental and moral manifestations are no longer elicited; the whole of the functions of relation become torpid, and remain in this state until the nervous system has been renovated, and adapted for the repetition of those functions, which, during the previous waking condition, had been exhausted. This state constitutes *sleep;* which, consequently, may be defined—the periodical and temporary suspension of all, or most, of those functions that connect us with the universe. The suspension occurs in those functions and in those only; and hence the consideration of sleep, in many physiological treatises, has immediately followed that of the functions of relation.

The nutritive functions continue regularly in action from the earliest period of fœtal formation; before mental manifestations exist in the embryo, and during sleep. For them there is no cessation, and scarcely any declension of activity, until the decadency of the frame affects them along with the whole of the machinery. Sleep, in the language of poetry, has been compared to death; and Dr. Good has stated that the resemblance between them is not less correct upon the principles of physiology, than it is beautiful among the images of poetry. "Sleep is the death or torpitude of the voluntary organs, while the involuntary continue their accustomed actions. Death is the sleep or torpitude of the whole." Physiologically, the difference appears to us considerable. During the whole of sleep a process of renovation is probably going on in the organs of animal life, which adapts them for subsequent activity, and contrasts signally with the state of annihilation that constitutes death; hence the important difference between healthy sleep, and the state of coma induced by any morbid cause; from which the patient is aroused languid and exhausted, instead of active and recruited. The fœtus in utero is also described by some as being in a perpetual sleep, until aroused by the new actions established at birth. It ap-

pears to us, that there must be, even in this case, alternations of activity and suspension in the nervous functions. We have seen elsewhere, that they are manifestly more or less exerted during intra-uterine existence; nervous energy must therefore be expended; and renovation,—to a much less extent, it is true, than in the new-born child,—be necessary.

Linnæus, under the term *somnus plantarum*, expresses a peculiar state in the constitution of many plants during the night, as evinced by a change of position,—generally a drooping or folding together of their leaves or leaflets; such a change being occasioned by the withdrawal of the stimulus of light, and, probably, it has been conceived, constituting a state of rest to their vital functions; but it is obvious, that there can be no similitude between this condition and that of the sleep of animals, which is confined to the functions of relation,—functions that do not even exist in the vegetable.

The approach of sleep is indicated by signs, that are unequivocal, and referable to the encephalon. The great nervous centre of animal life, feeling the necessity for renovation, an internal sensation arises in it, as well as in the whole of the nervous system over which it presides, termed *sleepiness*, or the *sensation*, or *want*, or *desire of sleep*, which, provided the waking state has been protracted, ultimately becomes irresistible, and often draws on sleep in spite of every effort to the contrary. It is affirmed, that boys, exhausted by exertion, dropped asleep amid the tumultuous noise of the battle of the Nile; and the fatigued soldier has been often known to sleep amid discharges of artillery. An engineer has been known to fall asleep within a boiler whilst his fellows were beating it on the outside with their heavy hammers. Noises will at first prevent sleep, but the desire is ultimately so invincible, that they cease to produce any effect. In the noisy inns of large towns, where the perpetual arrivals and departures of travellers keep up an incessant din and confusion, sleep may be for a time withheld, but it ultimately supervenes, although the tumult may be even tenfold; and if the noise should, from any cause, suddenly cease, the individual will probably awake. It is reported of the proprietor of some vast iron-works, who slept close to them, notwithstanding the noise of sledge-hammers, forges and blast-furnaces, that he would immediately awake if any interruption occurred during the night. This effect of habit is seen in the infant, which has been accustomed to the cradle. The moment the motion and noise of the cradle, or the sound of the nurse's voice,—if she has been in the custom of singing the child to sleep,—ceases, it awakes.

When the desire for sleep sets in vigorously, the animal functions become more obtuse, until they progressively fail to be exerted. The cessation does not occur in all simultaneously. The power of volition is gradually lost over the muscles; the eyes cannot be kept open; the upper eyelid falls, and if we attempt to raise it again, it appears to be weighed down; the arms fall where gravity would

take them; the extensor muscles of the back, deprived of volition, cease to contract, and the head falls suddenly forward, occasioning *nodding*, which rouses the brain to momentary action, to be again, however, lost. If the individual be in the erect attitude, his limbs bend under him; and if in the sitting posture, the head gradually falls upon the chest; the extensors of the trunk no longer contract with sufficient force to obviate its tendency to fall forwards; and the attitude, unsupported, can no longer be maintained. The same gradual suspension occurs in the muscular movements, concerned in speech and in the production of the voice, which becomes feeble, confused, broken and ultimately lost. All the strictly voluntary muscles have, in short, their action suspended, if we except the orbicularis palpebrarum muscle, which, according to Broussais, now contracts to close the eye and shut off the stimulus of light.

If we determine to resist the desire for sleep, we yawn and stretch, for the reasons elsewhere assigned, and endeavour to arouse the functions to renewed activity. If the state of wakefulness has not been long protracted, we are successful; but all our endeavours fail, if the nervous system be so far exhausted as to render reparation indispensable.

From the commencement of sleepiness, the action of the senses is enfeebled, and gradually suspended. The sight yields first, the closure of the eyelids preventing the organ from being impressed by its special irritant. The smell yields after the taste; the hearing after the smell; and, lastly, the touch sleeps; although the appropriate irritants may continue to reach the organs of these senses. All the internal sensations, hunger, thirst, &c., as well as the morbid sensation of pain, are no longer appreciated. The intellectual and moral manifestations exhibit, from the commencement of the feeling of heaviness, the languor which pervades the frame. The will gradually ceases to control the functions that are under its domain, until ultimately the power of volition is lost. In the less perfect kind of sleep, or in *slumber*, the ideas flit in a disorderly manner, constituting a kind of delirium; but, when sleep is complete, the whole encephalic organ appears to be at rest, and perceptions are no longer accomplished: special irritants may be applied to the external senses, but they excite no sensation. Many physiologists affirm, that the internal functions of nutrition acquire more energy during sleep; but Broussais properly disputes the affirmation, and maintains, that the want of action in the senses, muscles, and intellect, must necessarily occasion diminished energy in the nutritive functions. During sleep, circulation and respiration appear to be retarded; perspiration is less active, and digestion more tardy than in the waking condition. The difference in the last respect is so great, that, as Broussais remarks, the appetite recurs many hours before the usual time where long watching is indulged, and an additional meal becomes necessary; proving the truth of the old French proverb,—"*qui dort dine*"—"who sleeps, dines." Secretion, nutrition, and calorification are also

less energetically performed than usual. Absorption, alone, according to some is more active; but there seems not to be sufficient reason even for this assertion. This notion of the greater activity of the nutritive organs is as old as Hippocrates, and has been acquiesced in by almost all subsequent writers without examination, especially as it seemed to show a kind of alternation and equipoise between the respective periods of activity of animal and organic life.

During sleep, then, all the animal functions are suspended, and the body generally remains in a state of semiflexion, the one which, as we have elsewhere seen, requires little natural effort. To this, however, there are numerous exceptions depending upon habit. The easiest position for the body is perhaps on the back. It is the one assumed in extreme debility, when the prostration is so great that the individual sinks down in the bed like a dead weight; but the extensor muscles of the thigh and leg, under such circumstances, become fatigued, and relief is obtained by drawing the feet upwards so as to elevate the knees. This is a common attitude in the most debilitating maladies, and is often maintained until within a short time prior to dissolution. Sleep can persist with the exercise of certain muscles. Couriers, on long journeys, will nap on horseback, and coachmen on their boxes. The author has seen a servant boy erect, and asleep in the intervals between the demand for his services at the table.

During the first sleep, the suspension of the animal functions is the most complete; but, towards morning, some of them becomes less asleep, or more excitable than others. The intellectual and moral faculties are frequently inordinately active, giving occasion to dreams, which, with some individuals, occupy a great portion of the period allotted to rest. The sense of tact, too, is easily roused. If we lie in a position, which is disagreeable, it is soon changed; the limbs are drawn away, if irritated in any manner; the clothes are pulled up, if the air is disagreeably cold, &c. The sense of sight and the voluntary motions are least readily aroused, so that those functions, which fall asleep the last, are most easily awakened, and they gradually resume their activity in the order in which they lost it.

After six or eight hours of sleep,—more or less according to circumstances,—the individual awakes, not generally at once, however; a state of slumber, like that which preceded sleep, now succeeds it. The organs, which are the last to resume their activity, require to be excited to the performance of their functions. The eyes are rubbed; stretching is indulged, which recalls the nervous influx to the muscles; whilst sighing and yawning arouse the muscles of respiration, and compensate, in some measure, for the minor degree of aeration of the blood accomplished during sleep. The urine is discharged, and the phlegm, which may have collected in the air passages, expectorated: these excretions have accumulated during sleep, because, owing to diminished sensibility, the call for their evacuation

has not been as urgent. In cases of catarrh, accompanied by copious mucous secretion, and in phthisis pulmonalis, the fluid will collect in surprising quantity in the air-passages during sleep, and it is expectorated as soon as the brain is sufficiently aroused to respond to the sensation.

When the individual is fully awake, the energy, with which the animal functions are exercised, exhibits that the nervous system must have entirely recruited during its state of comparative inaction. The period of sleep, necessary for this purpose, varies in different individuals, and at different ages. Some require eight or ten hours; others not more than three or four; and others are said to have been contented, throughout the whole course of a long life, with not more than one or two. Men of active minds, whose attention is engaged in a series of interesting employments, sleep much less than the lazy and the listless. General Pichegru informed Sir Gilbert Blane, that in the course of his active campaigns he had, for a whole year, not more than one hour of sleep, on an average, in the twenty-four hours. The great Frederick of Prussia, and the yet more great Napoleon, are said to have spent a surprisingly short time in rest; but, with respect to the latter, the fact is controverted by one, who had excellent opportunities for observation. It is probable, that in these cases the sleep is more intense, and that such of the animal functions, as require rest indispensably, are completely suspended during the whole period consigned to it. These are the functions of voluntary motion more particularly; the intellectual and moral faculties requiring a much shorter period of repose, as is manifest by their incessant activity during dreaming,—a condition, which, with some, continues through almost the whole night. The same individual, too, will spend a shorter time in sleep, when strongly interested in any pursuit, than in the monotonous occurrences of ordinary life, and, when any subject occupies us intently, it will frequently keep us awake in spite of ourselves; but, although the period of sleep may be protracted much beyond the accustomed hour by unusual excitation, the effect of the stimulus becomes insufficient, and sleep comes on under circumstances, which appear most unfavourable to it. The lunatic affords us a wonderful example of powerful resistance to sleep and fatigue, or rather of the short period, which is necessary for the renovation of the nervous system, kept almost incessantly upon the stretch, as it is, in many of these distressing cases.

It has been a common remark, that women require more sleep than men, and Georget assigns them a couple of hours more,—allotting to men six or seven hours, and to women eight or nine; but Dr. Macnish judiciously doubts, whether the female constitution requires more sleep than the male; at least, he says, it is certain, that women endure protracted wakefulness better than men, "but whether this may result from custom is a question worthy to be considered." The fact is, however, too general to allow custom to be invoked.

It would seem, indeed, that the female frame, although far more excitable than that of the male, is longer in having that excitability exhausted, and that the recuperative powers are greater, so that the excitability, when exhausted, is more readily restored. The notion, that the female needs more rest than the male, appears to be traditionary, and like most traditions, to have been handed down from one individual to another, without due examination. The degree of muscular and mental exertion, to which the male is accustomed, would seem, to indicate that a longer period of rest ought to be required by him to admit of the necessary restoration of excitability.*

In infancy and youth, whilst the animal functions are extremely active, the necessity for sleep is greatest; in mature age, where time is more valued and the cares are more numerous, it is less indulged; and the aged may be affected in two opposite ways; they may be either in a state of almost constant somnolency, or their sleep may be short and light.

Sleep has been divided by the physiologist into the *complete*, and *incomplete*. The former is characterized by suspension of all the animal functions; a state, the existence of which has been doubted by many. Certain it is, that it can occur but rarely, only when all the organs have stood in equal need of rest and renovation; and when none have preserved, from the preceding state of waking, a peculiar susceptibility for action. The nearest approach to it occurs in the first hours of repose: after this, it becomes incomplete; some of the functions are not equally sound asleep, and consequently respond to excitants with different degrees of facility; whilst the various organs do not require the same time for reparation, and therefore awake at different intervals; hence, dreams arise, which occur chiefly towards morning, or after the sleep has become incomplete; that is, when some of the animal functions are more or less actively, but irregularly, exercised.

Anciently, *dreams* were regarded as supernatural phenomena, under the control of the children of Somnus or Sleep,—Morpheus, Phobetor or Icelos, and Phantasos. These three children, according to Ovid, were capable of transforming themselves into any form; the employment of Morpheus being to counterfeit the forms of men; Phobetor imitated the likeness of brutes and objects of terror; and Phantasos that of inanimate creatures.

For a long time, dreams were supposed to reveal future events by types and figures; as when Hecuba dreamed she had conceived a firebrand, and Cæsar, that he should lie with his mother; which was interpreted, that he should enjoy the empire of the earth,—the common mother of all living creatures. Oneiromancy was an encouraged art, and ministered largely to the credulity and superstition of

* See, on the hygienic relations of sleep, the Author's 'Elements of Hygiène,' from p. 444 to p. 455 inclusive.

the people. Strange to say, there are yet those, who look upon dreams to be typical and instructive, and consequently supernatural! Mr. Baxter and Bishop Newton openly maintained this doctrine. They divide dreams into two kinds,—good and evil,—and conceive, that two kinds of agents, good and evil spirits, are concerned in their production; they consequently account for the one or the other sort of dreams, according as the one or the other kind of agents obtains a predominancy! It is not necessary to combat these views,—which ought of course, to be as applicable to animals as to man,—especially as they are universally discarded. Dreaming is now properly considered to be an irregular action of the brain, in which the great controlling power of the will has suspended its agency, and allowed the memory and imagination unlimited sway, so that the most singular and heterogeneous ideas are formed,—still kept, however, somewhat in train by the force of association. At times, indeed, this influence is so great, that every part of the dream appears to go on in the most natural and consistent manner. We witness the scenes, that have occurred during our waking hours; and we seem to see, hear, walk, talk, and perform all the ordinary offices of life. The mind reasons, judges, wills, and experiences all the various emotions. Generally, the whole process is confined to the brain, but, at times, the muscles are thrown into action, and the expression of the feelings and emotions occurs, as in the waking state. The dreamer moves, speaks, groans, cries, sings, &c. and if the dream concerns the generative function, the external organs respond, and emission takes place in the male to such an extent, occasionally, as to constitute a true disease, or to be the cause of such,—the *paroniria salax* of Good, the *gonorrhœa dormientium*, or *night pollution* of others. During the prevalence of a passion, too, the nutritive organs, in which its effects are experienced whilst awake, may be equally concerned during sleep. The respiration is short and interrupted, and sighs, groans, or laughter, according to the character of the emotion, are elicited; the heart beats with more or less violence, and this state of excitement will often continue after the individual has been completely aroused. The *nightmare*, *ephialtes*, or *incubus*, affords us an example of suffering as intense as could well be experienced during our waking moments. A sensation of distressing weight is felt at the epigastrium, and of impossibility of motion, speech or even respiration: the dreamer fancies that some horrible form, or some ferocious being is approaching him, and that all chance of escape is precluded; or that he is about to fall, or is falling, from a lofty precipice; and the anguish, which he suffers, is indicated by loud groans, or by such painful feelings, apparently in the organs to which the emotions are referred, that he wakes. The ideas, at these times, are even more vivid than during the waking condition; the perceptions, that predominate, not being detracted from by extraneous impressions.

On many of these occasions, when we awake, the dream is fresh

upon the memory; and, by resigning ourselves again to slumber, we can, at times, recall it, should it be of an agreeable character, or dispel it altogether by rousing ourselves thoroughly.

On account of the greater vividness of the ideas during sleep, and their freedom from all distraction, intellectual operations are sometimes effected in a surprising manner; difficulties being occasionally solved, which have obtained the mastery during waking. To a minor degree, every one must have experienced more or less of this. Composition, poetical or other, is often effected with the greatest facility; and a clue is occasionally afforded, which leads to the solution of previous difficulties. Cardan had a notion that he composed one of his works during sleep. Condillac, who attended greatly to this matter, remarked particularly, that, whilst engaged with his "*Cours d'Etude*," he frequently broke off a subject, before retiring to rest, which he developed and finished the next morning according to his dreams. Condorcet saw in his dreams the final steps of a difficult calculation, which had puzzled him during the day; and Dr. Gregory, of Edinburgh, composed thoughts, and clothed them in words, which were so just in point of reasoning, and so good in point of language, that he used them in his lectures, and in his written lucubrations. Voltaire, Lafontaine, Franklin, Coleridge, and others, have made similar remarks; and events of the kind must have occurred, in some shape, to almost every one. Dr. Good relates a singular instance which happened to a friend of his, who, amongst other branches of science, had deeply cultivated that of music, of which he was passionately fond. He was a man of irritable temperament, ardent mind, and most active and brilliant imagination; and "was hence," says Dr. Good, "prepared by nature for energetic and vivid ideas in his dreams." On one occasion, during his sleep, he composed a very beautiful little ode, of about six stanzas, and set the same to very agreeable music, the impression of which was so firmly fixed in his memory, that, on rising in the morning, he copied from his recollection both the music and the poetry.

In these cases, the will must direct, more or less, the intellectual process. It is scarcely conceivable, that the train of reasoning could go on so connectedly and effectively by association alone. That the will can, in some degree, be kept awake, or in a condition susceptible of being readily aroused, is shown by the facility with which we awake at a determined hour, and exercise a degree of watchfulness during sleep; as well as by the facts, previously mentioned, regarding the courier who sleeps on his horse, or the coachman on his box.

There is a kind of dreaming, in which the sleep is more complete than during ordinary dreams; where the body has, consequently, less capability of receiving impressions, but where the will has a certain degree of power over the muscles of voluntary motion. This is *somnambulism*, or *sleep-walking*. During the con-

tinuance of this state, the individual can apparently see, hear, walk, write, paint, speak, taste, smell, &c., and perform his usual avocations, yet remain so soundly asleep, that it is impossible to awake him without making use of violence. Cases are on record, and of an authentic nature, of individuals who have risen from bed asleep, with their eyes closed, and have not only walked about the room or house, going up or down stairs, finding their way readily and avoiding obstacles, but have passed with safety through very dangerous places, as windows, or on the roofs of houses. They have executed, too, yet more difficult feats; such as dressing themselves, going out of doors, lighting a fire, bathing, saddling and bridling a horse, riding, composing verses, &c., and executing all the actions of life correctly, and even acutely; yet they have been asleep during the whole of these acts. The eyes have been shut, or if open, have been incapable of perceiving the brightest light held before them; and the iris has not exhibited its irritability by contracting, so that it is doubtful whether the ordinary functions of the eyes are generally executed during somnambulism; and the fact, of the serious accidents that occasionally befall the sleep-walker, is in favour of this conclusion. It must be remarked, however, that, in the opinion of some physiologists, the sight is awake and employed, and there are cases which strongly favour the idea.

A peculiarity of ordinary somnambulism is, that the train of thoughts is usually directed towards one point, and this so profoundly, that notwithstanding the activity of the imagination, and the firm hold it takes on the mind, no recollection is retained of the occurrences during sleep, after the individual awakes, either spontaneously, or by being forcibly aroused.

Animal magnetism would seem to be capable of inducing a peculiar kind of somnambulism, in which new faculties appear to be acquired, and intellectual operations to be executed, which are of the most astonishing character. Of these, the author has seen nothing himself; but the records of the *Académie Royale de Médecine*, of Paris, contain many such instances. A singular case of somnambulism is given by Dr. Belden, of Springfield, Vermont. It occurred in a young female, 17 years of age, and the phenomena were attested by numerous observers. One striking circumstance in this case was the astonishingly developed impressibility of the eye. As an evidence of this, when Dr. Belden, in order to test the sensibility of that organ, took one evening a small concave mirror, and held it so that the rays, proceeding from a lamp, were reflected upon her closed eyelid, when the light was so diffused, that the outline of the illuminated space could scarcely be distinguished, it caused, the moment it fell on the eyelid, a shock equal to that produced by an electric battery. This female could see as well, apparently, when the eyes were closed as when they were open. The details of this case—and indeed of every case—of somnambulism are full of interest to the mental philosopher.

The causes of imperfect or incomplete sleep, and hence of dreams, are various. The fact, already referred to, of the different organs of the animal functions having their distinct periods of waking and rest, would induce us to suppose, that it ought not to be always equally profound and durable: yet there are individuals whose sleep is nearly complete throughout; but they are not many. The previous occupation of the sleeper exerts great influence. If it has been of a fatiguing nature, all the faculties rest equally long and soundly; but if the fatigue extends beyond the due point, a degree of excitability of the brain is left which renders it extremely liable to be aroused. In this way, we understand why dreams should bear upon subjects that have long occupied the mind in its waking state; the tension of the mind on those subjects having left considerable excitability, as respects them, and a disposition to resume them under the slightest irritation.

The presence or absence of irritants—external or internal—exerts likewise a great effect on the soundness of sleep, and the formation of dreams. The stillness of night and the absence of light are hence favourable to repose: the position, too, must be one devoid of constraint; and the couch soft and equable, and especially such as the individual has been accustomed to use. Sleep is impracticable in a badly-made bed; and every one must have experienced the anti-soporific influence of a strange bed, the arrangement of which, as to quantity, pillows, &c. differs from that to which he has been habituated. It is not, however, by external irritants that the sleep is usually disturbed. The state of the system itself will react upon the brain, and give occasion to broken sleep, and to dreams of the most turbulent character. Irritations, existing in the viscera, are frequently the cause of dreams,—in children more especially; and a hearty supper, especially if of materials difficult of digestion, will bring on the whole train of symptoms that characterize nightmare. In like manner, anything that impedes the action of the functions of respiration, circulation, &c. may occasion the wildest phantasies.

All these internal impressions are more vividly perceived for the reasons already stated. The nervous system is no longer excited by the ordinary impressions from the external senses; and if these internal impressions are insufficient to prevent sleep alogether, they may excite dreams.

During this incomplete kind of sleep, the external sensations are not wholly at rest; particularly that of touch or tact, which, as it is the last to sleep, is the first to awake. Impressions, made on it, will excite the most exaggerated representations in the brain, in the shape of dreams. The bite of a flea appeared to Descartes the puncture of a sword: an uneasy position of the neck may excite the idea of strangulation: a loaded stomach may cause the sleeper to feel as if a heavy weight,—a house, or a castle, or some powerful monster,—were on his stomach. A person, having had a blister applied to his head, imagined that he was scalped by a party of Indians. Moreau de la

Sarthe gives the case of a young female, who, from the application of her cold hand against her breast, when asleep, dreamed that a robber had entered her apartment and had seized hold of her. Galen dreamed, that he had a stone leg, and, on waking, found that his own was struck with paralysis. Mr. Dugald Stewart gives a similar case, to show how an impression made upon the body, during sleep, may call up a train of associated ideas, and thus produce a dream. A gentleman, (Dr. Gregory,) who, during his travels, had ascended a volcano, having occasion, in consequence of indisposition, to apply a bottle of hot water to his feet when he went to bed, dreamed that he was making a journey to the top of Mount Ætna, and that he found the heat of the ground almost insupportable. Sir Walter Scott mentions an analogous instance, which was told him by the nobleman concerned. He had fallen asleep, with some uneasy feelings arising from indigestion, which brought on the usual train of visionary terrors. At length, they were all summed up in the apprehension, that the phantom of a dead man held the sleeper by the wrist, and endeavoured to drag him of out of bed. He awoke in horror, and still felt the cold, dead, grasp of a corpse's hand on his wrist. It was a minute before he discovered that his own left hand was in a state of numbness, and with it he had accidentally encircled his right arm.

If, again, the organ of hearing be wakeful, the dreamer may hear an individual speak to him and may reply; so that occasionally secret thoughts and feelings have been elicited. The author has himself replied several times connectedly in this manner; and he has been able to lead on others, especially children,—whose sleep is often interrupted by the existence of irregular internal impressions,—to answer a few times in the same way.

In the explanation of the cause of dreaming, we have the most plausible application of the theory of Gall regarding the plurality of organs in the brain. Every explanation, indeed, takes for granted, that certain faculties are suspended whilst others are active. Gall's view is, that, during sleep, particular organs of animal life enter into activity; and hence, that the perceptions and ideas, which depend on these organs, awake; but, in such case, their activity takes place without any influence of the will;—that when one organ only is in activity, the dream is simple: the dreamer caresses the object of his affection; he hears melodious music, or fights his enemies, according as this or that organ is exercising its functions;—that the greater the number of organs in activity at the same time, the more confused or complicated will be the dream, and the greater the number of extravagancies;—that, when the organs are exhausted by watching and labour, we generally do not dream during the first hours of sleep, unless the brain is extremely irritable; but, in proportion as the organs get rid of their fatigue, they are more disposed to enter into activity, and hence, near the time for waking, we dream more and with greater vivacity. "Dreaming, consequently," he concludes, "is only a state of partial waking of animal life; or, in

other words, an involuntary activity of certain organs, whilst others are resting."

In many respects, the state of the mind, during dreaming, resembles that in the delirium of fever, as well as in insanity. The imagination and memory may be acting with unusual vivacity, whilst the perceptions or the judgment may be most erroneous;—at times, the perception being accurate and the judgment suspended, so that the individual may be most incoherent; whilst, at others, the perceptions may be inaccurate and the judgment right, so that the individual will reason correctly from false premises. As in dreams, too, the delirious may have their ravings modified by impressions made on the external senses. Sir Walter Scott cites the case of a lunatic, confined in the infirmary of Edinburgh, whose malady had assumed a gay turn. The house, in his idea, was his own, and he contrived to account for all that seemed inconsistent with his imaginary right of property;—there were many patients in it, but that was owing to the benevolence of his nature, which made him love to relieve distress. He went little, or rather never abroad,—but then his habits were of a domestic and rather sedentary nature. He did not see much company, but he daily received visits from the first characters in the celebrated medical school of the city, and he could not, therefore, be much in want of society. With so many supposed comforts around him, with so many visions of wealth and spendour, one thing alone disturbed his peace. "He was curious," he said, "in his table, choice in his selection of cooks, had every day a dinner of three regular courses and a desert, and yet somehow or other, everything he ate tasted of porridge." The cause of this was, that the lunatic actually ate nothing but this at any of his meals: and the impression made upon his palate was so strong as to modify his delusion.

Nearly allied to dreams, in its physiology—or more properly, perhaps—pathology, is the subject of *hallucinations*, *spectral illusions*, or *waking dreams*, in which the mind may be completely sound, and yet the cerebral or percipient part of the brain, concerned in the senses, be so deranged as to call up a series of perceptions of objects, which have no existence except in the imagination. Such hallucinations are constant concomitants of insanity, delirium, and dreaming; but, they may occur also, when the individual is wide awake, and in the full possession of reasoning powers; he may see the phantasm, but, at the same time, totally disbelieve in the existence of any extraneous body. The most common illusions of this kind affect the senses of sight and hearing.

It has fallen to the lot of the author to meet with some singular and serious cases of this affection; where, for example, the individual, wide awake, has heard the doors of his house violently slammed, his windows thrown up and down, the bells set a ringing, himself subjected to personal violence; yet there has been no slamming of doors, no throwing up and down of windows, no ringing of bells, no

personal violence; the whole has been an illusion, a waking dream, and of this no one has been more entirely aware than the sufferer himself.

A few years ago, the author was consulted by a most respectable citizen of Virginia, respecting his state of health as well as an illusion of this nature. He was one of the Board of visitors at West Point, where his duty called him to inspect the demonstrations of the pupils on the black-board. For months after his return to Virginia, he saw the black-board with its demonstrations constantly before him. He had previously experienced an attack of paralysis, and, when he applied to the author, he was labouring under marked evidences of predisposition to a farther attack of encephalic mischief, of which the illusion in question was doubtless one.

One of the most impressive cases of this kind is that of Nicolai, the eminent bookseller of Berlin, which has been detailed by Dr. Ferriar, and by Dr. Haslam, in his "Medical jurisprudence, as it relates to Insanity,"—a tract, reprinted in this country, along with others, by Dr. Cooper. Nicolai laid his case before the Philosophical Society of Berlin. He traced his indisposition, for it was manifestly such, to a series of disagreeable incidents that had befallen him. The depression, thus induced, was aided by the consequences of neglecting a course of periodical bleeding to which he had accustomed himself. This state of health brought on a disposition to spectral illusions, and, for a time, he was regularly haunted by crowds of persons entering his apartment, and addressing him or occupied solely in their own pursuits, until as his health was restored, they gradually disappeared, and ultimately left him entirely. Yet Nicolai, who was a man of unusually strong intellect, was throughout satisfied, that they were mere hallucinations.

The cases of this kind, now on record, are many and curious. Every one engaged in extensive practice, or in frequent communion with the world, must have seen or heard of them. Some, of a deeply interesting character, are detailed by Sir David Brewster, Dr. Abercrombie, and Dr. Macnish; there are none, however, which strike us as more extraordinary, and which are, at the same time, more elucidative of the subject, than the following, related by Sir Walter Scott.

It was told him by the medical gentleman under whose care it fell, and of whom "I can only say," says Sir Walter, "that if I found myself at liberty to name him, the rank, which he holds in his profession, as well as his attainments in science and philosophy, form an undisputed claim to the most implicit credit."

This gentleman was called to attend a person, who stood high in a particular department of the law, which often placed the property of others subject to his discretion and control, and whose conduct was therefore open to public observation. He had, for years, borne the character of a man of unusual steadiness, good sense, and integrity. He was, at the time of the physician's visit, confined chiefly to his chamber, sometimes to his bed; yet occasionally attending to

business, and exerting his mind, apparently with all its usual strength and energy, in the management of the weighty matters entrusted to him; nor did there, to a superficial observer, appear anything in his conduct, while so engaged, that could argue vacillation of intellect or depression of mind. His outward symptoms indicated no acute or alarming disease; but slowness of pulse, absence of appetite, difficulty of digestion, and constant depression of spirits seemed to draw their origin from some hidden cause, which the patient was determined to conceal. The deep gloom, the embarrassment, which he could not conceal from his friendly physician, the brevity and obvious constraint with which he replied to the interrogatories of that gentleman, induced him to take other methods for attaining correct information. He applied to the sufferer's family, to learn, if possible, the source of that secret grief, which was evidently corroding him; yet not the slightest clew could be discovered. He had finally recourse to serious argument with the invalid himself, urging to him the folly of devoting himself to a lingering and melancholy death, rather than tell the subject of affliction, which was thus wasting him. He specially pressed upon him the injury he was doing his own character, by suffering it to be inferred, that the secret cause of his dejection and its consequences were something too scandalous or flagitious to be made known; bequeathing, in this manner, to his family, a suspected and dishonoured name, and leaving a memory, with which might be associated the idea of guilt, which the criminal had died without confessing. The patient, moved more by this species of appeal than by any that had been previously urged, expressed his desire to speak out frankly to the doctor. Every one else was removed, and the door of the sick-room made secure, when he began his confession as follows:—"You cannot, my dear friend, be more conscious than I, that I am in the course of dying under the oppression of the fatal disease which consumes my vital powers; but neither can you understand the nature of my complaint, and manner in which it acts upon me, nor if you did, I fear, could your zeal and skill avail to rid me of it."—"It is possible," said the physician, "that my skill may not equal my wish of serving you: yet medical science has many resources, of which those, unacquainted with its powers, never can form an estimate. But, until you plainly tell me your symptoms of complaint, it is impossible for either of us to say, what may or may not be in my power, or within that of medicine." "I may answer you," replied the patient, "that my case is not a singular one, since we read of it in the famous novel of Le Sage. You remember, doubtless, the disease of which the Duke D'Olivarez is there stated to have died?" "Of the idea," replied the doctor, "that he was haunted by an apparition, to the actual existence of which he gave no credit, but died, nevertheless, because he was overcome and heart-broken by its imaginary presence." "I, my dearest doctor," said the sick man, "am in that very case; and so painful

and abhorrent is the presence of the persecuting vision, that my reason is totally inadequate to combat the effects of my morbid imagination, and I am sensible I am dying a wasted victim to an imaginary disease." The medical gentleman listened attentively to his patient's statement, and avoiding, for the time, any opposition to the sick man's preconceived fancy, contented himself with a more minute inquiry into the nature of the apparition with which he conceived himself haunted, and into the history of the mode by which so singular a disease had obtained the mastery of his imagination, secured, as it seemed to be, against so irregular an attack by strong intellectual powers. The patient replied, that its advances had been gradual, and, at first, not of a terrible, or even disagreeable, character. To illustrate this, he gave the following account of its progress.

"My visions commenced two or three years since, when I found myself, from time to time, embarrassed by the presence of a large cat, which came and disappeared I could not exactly tell how, till the truth was finally forced upon me, and I was compelled to regard it as no domestic household cat, but as a bubble of the elements which had no existence save in my deranged visual organs or depraved imagination. Still I had not that positive objection to the animal, entertained by a late gallant Highland chieftain, who has been seen to change to all the colours of his own plaid, if a cat happened by accident to be in the room with him, even though he did not see it. On the contrary, I am rather a friend to cats, and endured with so much equanimity the presence of my imaginary attendant that it had become almost indifferent to me; when, within the course of a few months, it gave place to, or was succeeded by, a spectre of a more important sort, or which at least had a more imposing appearance. This was no other than the apparition of a gentleman-usher, dressed as if to wait upon a lord-lieutenant of Ireland, a lord high commissioner of the Kirk, or any other who bears on his brow the rank and stamp of delegated sovereignty. This personage, arrayed in a court dress, with bag and sword, tamboured waistcoat, and chapeau-bras, glided beside me like the ghost of Beau Nash; and whether in my house or in another, ascended the stairs before me, as if to announce me in the drawing-room; and sometimes appeared to mingle with the company, though it was sufficiently evident, that they were not aware of his presence, and that I alone was sensible of the visionary honours which this imaginary being seemed desirous to render me. This freak of the fancy did not produce much impression upon me, though it led me to entertain doubts on the nature of my disorder, and alarm for the effect it might produce upon my intellects. But that modification of my disease had likewise its appointed duration. After a few months, the phantom of the gentleman-usher was seen no more, but was succeeded by one, horrible to the sight, and distressing to the imagination, being no other than the image of death itself—the apparition of a *skeleton*. Alone or in com-

pany, the presence of this phantom never quits me. I, in vain, tell myself a hundred times over that it is no reality, but merely an image summoned up by the morbid acuteness of my own excited imagination, and deranged organs of sight. But what avail such reflections, while the emblem at once and presage of mortality is before my eyes, and while I feel myself, though in fancy only, the companion of a phantom, representing a ghastly inhabitant of the grave, even while I yet breathe on the earth? Science, philosophy, even religion, has no cure for such a disorder; and I feel too surely, that I shall die the victim to so melancholy a disease, although I have no belief whatever in the reality of the phantom which it places before me."

The physician was distressed to find that this visionary apparition was so strongly fixed in the imagination of his patient. He ingeniously urged the sick man, who was then in bed, with questions concerning the circumstances of the phantom's appearance, trusting that he might lead him, as a sensible man, into such contradictions and inconsistencies as might bring his common sense, which seemed to be unimpaired, so strongly into the field as to combat successfully the fantastic disorder which produced such fatal effects. "This skeleton, then," said the doctor, "seems to you to be always present to your eyes?" "It is my fate, unhappily," replied the invalid, "always to see it." "Then I understand," continued the physician, "it is now present to your imagination?" "To my imagination it certainly is so," answered the sick man. "And in what part of the chamber do you now conceive the apparition to appear?" the physician inquired. "Immediately at the foot of my bed, when the curtains are left a little open," answered the invalid; "the skeleton, to my thinking, is placed between them, and fills the vacant space." "You say you are sensible of the delusion," said his friend; "have you firmness to convince yourself of the truth of this? Can you take courage enough to rise and place yourself in the spot so seeming to be occupied, and convince yourself of the illusion?" The poor man sighed and shook his head negatively. "Well," said the doctor, "we will try the experiment otherwise." Accordingly he rose from his chair by the bed-side, and placing himself between the two half-drawn curtains, at the foot of the bed, indicated as the place occupied by the apparition, he asked if the spectre was still visible? "Not entirely so," replied the patient, "because your person is between him and me; but I observe his skull peering above your shoulder." The doctor resorted to other means of investigation and cure, but without success. The patient sank into deeper and deeper dejection, and died in the same distress of mind in which he had spent the latter months of his life. The circumstances of his singular disorder were concealed, so that he did not, by his death and last illness, lose any of the well-merited reputation for prudence and sagacity, which had attended him during the whole course of his life.

These are striking cases of the illusions that may occur during even our waking moments; and they may, doubtless, account for some of the stories of apparitions, of which so many are upon record. In the hypochondriac, we meet with all kinds of hallucination, and it is one of the most striking of the symptoms of every variety of insanity; but, in the cases we have adduced, notwithstanding the constancy and permanency of the illusion, the individual himself was entirely satisfied, that the whole affair had no real existence. Had he believed in the existence of the phantom, and acted from a conviction of its reality, he might, with propriety, have been deemed insane, *quoad hoc*. An instance of this kind is told in the Memoirs of the Count Maurepas of one of the princes of the house of Bourbon, who supposed himself to be a plant, and, after having fixed himself in the garden, called upon his servant to come and water him. His belief argued unsoundness of mind, yet even here the hallucination, we are told, appeared to be confined to this subject.

In youth, when the imagination is extremely vivid, we can call up images in the mind at pleasure, varying them as we may think proper. In the nervous, the delicate and the imaginative, uneasy sensations can be experienced, when and where the individual wishes. After sedentary habits, long continued, the author has been able to experience pain in any part of the system, where he has chosen; and to make it shift at pleasure from one organ to another.

In the cases of hallucination, which we have given at length, as well as in every other kind, the cerebral part of the organ of sense is directly or indirectly excited into action;—often by disease of the brain, or of some distant organ which reacts upon it. Hence it occurs as a precursor of apoplexy, epilepsy, or other cerebral affection, or it may accompany, or be aggravated by, disorder of the digestive function. It has been seen, that although the passions or emotions are cerebral phenomena, they are felt in the nutritive organs; and we can understand, how a disordered state of those organs may react upon the brain, and call up all kinds of illusions;—generally during sleep, but at times even during our waking moments. In this way, we account for the frightful dreams that follow an overloaded stomach, or that accompany impeded respiration or circulation. One of the most distressing symptoms of hydrothorax or water in the chest, which interferes more or less with both these vital functions, is the disturbed sleep, and the frightful sense of impending danger, which nightly distress the unfortunate sufferer.

It appears, then, that in all cases of hallucination, occurring in those of sound or diseased mind, asleep or awake, the cerebral or percipient part of the organ of the sense concerned is irresistibly affected, so as to call up the memory of objects, or to form others, which have no existence except in the imagination; but all this is accomplished without any impression being made upon the external

senses from without, even when these senses appear to be most actively exercised. In dreams, this must manifestly be the case. We see a friend long since dead; we parade the streets of a town, which we have never visited; see, hear, feel and touch the different objects. All this must be cerebral; and not less certainly is it the case in the hallucinations of insanity, or in those that occur in the waking condition. The object which we see, is not in existence, yet it is a regularly defined creation; a cat in one instance, a gentleman-usher in another, and a skeleton in a third. It cannot depend upon any depraved condition of the organ of sense, as in such case the representation of the mind would be amorphous, irregular, or confused; not a complete metamorphosis as is invariably the case. Yet we are surprised Sir Walter Scott should state, that he thinks "there can be little doubt of the proposition, that the external organs may, from various causes, become so much deranged as to make false representations to the mind; and that, in such cases, men, in the literal sense, really *see* the empty and false forms, and *hear* the ideal sounds, which in a more primitive state of society, are naturally enough referred to the action of demons or disembodied spirits. In such unhappy cases, the patient is intellectually in the condition of a general, whose spies have been bribed by the enemy, and who must engage himself in the difficult and delicate task of examining and correcting, by his own powers of argument, the probability of the reports, which are too inconsistent to be trusted to."

The explanation is poetic, but manifestly untenable.

A theory, which has been offered to account for the various spectral illusions, occurring in any of the modes we have mentioned, is—that, in all the organs of sense, the mind possesses the power of retransmitting, through the nervous filaments, to the expansion of the nerves that are acted upon by external objects, impressions, which these nerves have previously transmitted to the brain, and, that the vividness of the retransmission is proportional to the frequency with which the impressions have been previously transmitted; that these reproduced impressions are in general feeble in the healthy state of the body, though perfectly adapted to the purposes for which they are required; but, in other states of the body, they appear with such brilliancy as to create even a belief in the external existence of those objects from which the impressions were originally derived. "When the mind," says a writer on this subject, "acquires a knowledge of visible objects it is by means of luminous impressions, conveyed to the sensorium from each impressed point of the retina, through the corresponding filaments of the optic nerve, and when the memory is subsequently called upon, by an act of the will, to present to us an object, that has been previously seen, it does it by retransmission along the same nervous filaments, to the same points of the retina. In the first case, when the presence of the luminous object keeps up a sustained impression upon the nervous membrane, the filaments,

which transmit it to the brain are powerfully excited; but, in the process of retransmission by an effort of memory, the action of the nervous filaments is comparatively feeble, and the resultant impression on the retina faint or transient. When the memory, however, is powerful, and when the nervous filaments are in a state of high excitability, the impression becomes more vivid; and, as in the case of spectral illusions, it has the same strength and distinctness, as if it were produced by the direct action of luminous rays. In one case, the result of the impression and its retransmission to the retina is a voluntary act of the mind, but, in the other, it is involuntary, the controlling power being modified or removed, or the nerves being thrown into a state of easy excitation by some unhealthy action of the bodily organs."

According to this view, it is indispensable, that the perception, in every case of illusion, shall be referred to the nerves of the organ by which such perception is ordinarily effected; to the retina, if vision be concerned; to the auditory nerve, if audition; and so on. But this retransmission along the nerves appears to us to be wholly unnecessary. When an impression is made upon a sensitive surface, as we have elsewhere shown, sensation is not accomplished, until the impression has been conveyed to the brain by an appropriate organ, and the brain itself has acted; and if we interfere in any manner with the cerebral part of the function, perception is not effected. From the moment, however, that the action of the brain has taken place, the idea formed can be recalled by the exercise of memory; and, we have no doubt, that this could take place although the eyes were extirpated. The memory might call up previous perceptions, when the functions of the retina are entirely destroyed. Were it otherwise, it would be impossible for those, who have lost their sight from paralysis of the retina, of which many cases are constantly occurring, to call up any of the scenes and images, of which the brain took cognizance prior to the supervention of their blindness. In dreams, too, we exert every one of the senses; some with the greatest activity. We see, hear, taste, smell, feel; and, in addition to this, walk, run, fly, and execute the ordinary acts of life not only without apparent difficulty, but with a facility, that surprises us. Yet can we suppose, that, in all these cases, the feeling is actually produced by retransmission along the nerves to the organ to which it is referred?

It has been asserted, that when examination is carefully made it will be found, that the images, recalled by the memory, follow the motions of the head and of the eye; but, that this is not the case during sleep is manifest. The individual may remain precisely in the same position, and yet he will seem to move about in all directions in his dreams; will appear to see objects behind as well as before him; and in situations towards which it is impossible that the motions of his head and eye should be directed. Even in most of the illusions of our waking hours, the remark ought to be reversed.

The encephalic action is the first of the links in the chain of phenomena; and the motions of the head and the eye follow the images recalled by the memory. When the unfortunate subject of one of the cases of hallucination saw the gentleman-usher preceding him into company, and circulating amongst the assembled guests,—as well as when he observed the skeleton at the foot of his bed,—the perception, owing to disease, had so completely taken possession of a part of the encephalic organ of vision, that the idea was constantly in the mind; and volition being actively exercised, the head and the eye were directed towards the phantasm. Yet the perception was not so powerful, as to preclude the reception of impressions from without, as was shown by the skeleton seeming to be shut off by the body of the physician, so that the skull only was seen peering above his shoulder.

Another fact, which shows, that the whole phenomenon may be entirely encephalic, is the occurrence, familiar to the operative surgeon, of a patient, whose lower limb has been amputated, complaining of an uneasy sensation, as of itching, in a particular toe, and in a particular part of a toe. This is, at times, a symptom of an extremely distressing character. It is obviously impossible, that, in such case, there can be any external impression made on the part to which the feeling is referred; or that any retransmission can occur from the brain; the limb having been removed from the body. Broussais asserts, that if a person tells you he suffers in a limb which he no longer has, it is because he experiences irritation in the extremities of the divided nerve, but this, in no respect, removes the difficulty. The sensation is referred to a part, which has no existence except in the imagination.

But to return to sleep. We have said, that the object of sleep is to repair the loss, which the nervous system has sustained, during the previous condition of waking. This may, consequently, be regarded as the great exciting cause of sleep; but we have seen, also, that certain states of the mind may postpone the usual period of its recurrence. If, indeed, we allow the attention to flag, and suspend the due exercise of volition, sleep can be indulged at almost any hour of the day. In the same manner, any monotonous impression, or action of the brain in thought; the rocking of a cradle to the restless child; or the song of the nurse; the murmurs of a bubbling brook, &c. may soothe us to rest. A like effect is produced by substances, as narcotics, which, by a specific action on the nervous system, prevent the ordinary sources of irritation from being appreciated, as well as by certain morbid affections of the brain,—compression, concussion, inflammation, &c. In these cases, however, the sleep is morbid, and is an evidence of serious mischief,—often of fatal disease; whilst true sleep is as natural as the waking state, and is always—

"Man's rich restorative; his balmy bath,
That supples, lubricates and keeps in play
The various movements of that nice machine,
Which asks such frequent periods of repair!"

Yet Haller, Hartley, and numerous others have supposed, that natural sleep is dependent upon an accumulation of blood or other fluids in the vessels of the head, pressing upon the brain, and thus impeding its functions. In support of this opinion, it is asserted, that all the phenomena, which attend the sleeping state, seem to prove a determination of blood to the head. The face is flushed; the head is hotter; the skin more moist; and it is generally during the night, or when first awake, that bleeding from the nose and apoplexy take place: the frequency of erection during sleep is affirmed to be owing to the pressure exerted on the cerebellum, which, in the theory of Gall, is the encephalic organ of generation; and, lastly, it is argued, that narcotics, and vinous and spirituous liquors produce sleep by causing a similar congestion of blood within the cranium. The case, by no means unique, of the beggar whose brain was exposed, and in whom a state of drowsiness was induced when the brain was pressed upon, which could be increased by increasing the pressure, until at length he became comatose, has also been cited by Hartley and others. But all these are cases of morbid suspension of the animal functions, and are no more to be assimilated to true sleep, than the drowsiness, which Flourens found to prevail in his experiments on animals when the cerebral lobes were removed.

The believers in the hypothesis, that congestion of the vessels of the brain is the cause of sleep, consider, that the heaviness and stupor, observable in those who indulge too much in laziness and sleep, are owing to the long-continued pressure injuring the cerebral organs. Other physiologists have assumed the opposite ground, and affirmed, that during sleep the blood is distributed to the brain in less quantity, and is concentrated in the abdomen, to augment the action of the nutritive functions; whilst Cabanis holds, that during sleep there is a reflux of the nervous powers towards their source, and a concentration in the brain of the most active principles of sensibility.

On all these topics our ignorance is extreme. We know nothing of the state of the encephalon in sleep. Its essence is as impenetrable as that of every other vital function. Dr. Bostock asserts, that it is not more beyond our grasp than the other functions of the nervous system. This we admit: he has, indeed, afforded us in his own work indubitable evidences of our utter want of acquaintance with the essence of all those functions.

The state of sleep is as natural, as instinctive, as that of waking: both are involved in mystery, and their investigation, as Mr. Dugald Stewart has suggested, is probably beyond the reach of the human faculties.

Reverie has been considered to resemble sleep, and, in its higher grades, to be not far removed from the condition of somnambulism. It is characterized by the attention or volition being directed so intently towards particular topics, during wakefulness, that the impressions of surrounding objects are not appreciated. Various grades of this condition of the mind may be traced, from the slightest degree of *absence* or *brown study*, to a state of total abstraction, in which the attention is entirely wound up, and riveted to a particular subject. Most persons must have experienced more or less of this, when any subject of severe study, or any great gratification, anxiety, or distress has strongly occupied the mind. If engaged in reading, they may follow every line with the eye: turn over leaf after leaf, and at length awake from the reverie, which had occupied the imagination, and find, that not the slightest impression has been made on the mind, by the pages, which the eye had perused, and the hand had run over. If walking in a crowded street, they may have proceeded some way under the influence of revery, moving the limbs as usual, performing various acts of volition, winding safely among the passengers, avoiding the posts and other obstacles, yet so exclusively occupied by the conceptions of the mind, as to be totally unconscious of all these acts of their volition, and of the objects they have passed, which must necessarily have impressed their senses so as to regulate those actions, but, owing to the attention having been bent upon other topics, the perceptions have been evanescent. In elucidation of the power of a high degree of revery to render an individual torpid to all around him, the case of Archimedes, at the time of his arrest, has been quoted by writers. When the Roman army had at length taken Syracuse by stratagem, which the tactics of Archimedes had prevented them from taking by force, he was shut up in his closet, and so intent on a geometrical demonstration, that he was equally insensible to the shouts of the victors, and the outcries of the vanquished. He was calmly tracing the lines of a diagram, when a soldier abruptly entered his room, and clapt a sword to his throat. "Hold, friend," said Archimedes, "one moment, and my demonstration will be finished." The soldier, surprised at his unconcern at a time of such extreme peril, resolved to carry him before Marcellus; but as the philosopher put under his arm a small box full of spheres, dials, and other instruments, the soldier, conceiving the box to be filled with gold, could not resist the temptation, and killed him on the spot.

It is to the capability of indulging to the necessary extent in this kind of mental abstraction, that we are indebted for the solution of every abstruse problem, relating to science or art, and for some of the most beautiful conceptions of the poet. From indulgence, however, in such abstractions, a habit is often acquired, which may be carried so far as to render the individual unfit for society, and to give him a character for rudeness and ill-breeding, of which he may

be by no means deserving. Some most amiable and estimable men have, from long habits of abstraction, contracted the *disease* (*aphelxia*,) as Good has constituted it, and have found the cure tedious and almost impracticable: at times, indeed, it appears to have terminated in mental alienation.

The difference between this state and that of sleep is, that the attention and volition are here powerfully directed to one object, so as to be torpid to the impressions of extraneous bodies; whilst sleep is characterized by a suspension or diminished exercise of these faculties.

CORRELATION OF FUNCTIONS.

The wonderful and complicated actions of the frame are variously correlated, to accomplish that astonishing harmony, which prevails in the state of health, as well as to produce the varied morbid phenomena,—often at a distance from the part originally diseased,—which characterize different pathological conditions. It is not, therefore, simply as a physiological question, that the study of the correlation of functions interests the medical inquirer. It is important to him in the study of every department, which concerns the doctrine of the healthy or diseased manifestations, and the modes adapted for their removal.

These correlations may be of various kinds;—*physical*, in which the effect exerted is entirely of a mechanical character; *functional*, in which the action of one organ is inseparably united to that of another, to accomplish a particular object; and *sympathetic*, in which there is no physical action or direct catenation of functions; but where an organ, at a distance from one affected, is excited to irregular or regular action in consequence of the condition of the latter.

In the description of the different functions, numerous opportunities occurred for showing the influence which organs, in the immediate vicinity of each other, may mutually exert so as to modify their functions. The action of the muscles,—particularly those that contract the larger cavities, as the abdomen and thorax,—on the parts with which they come in contact, must be entirely mechanical. In this way, the diaphragm and the abdominal muscles act in vomiting and defecation. During the operation of blood-letting, the flow of blood can be augmented by moving the muscles of the hand; and it is probable, that the constant motion of the muscles of respiration impresses a succussion on different organs, which may aid them in accomplishing their functions, although the effect of this is doubtless exaggerated. Every change of position, either of the whole body or of a part, has, likewise, some effect in modifying the actions performed by it or by neighbouring organs, although such effect may not be easily appreciable.

A similar case of mere mechanical influence, which seems to be important to the proper action of certain organs, is exhibited in the pulsation of the different arteries. It has been seen, that a succussion is in this way given to the brain, which appears to be necessary to it; for, if this source of stimulation is in any manner withdrawn, fainting is induced. Perhaps, however, the strongest case, that can be offered, of modification of function by mechanical causes, is that

of the gravid uterus, which, by its pressure, gives rise to numerous symptoms in other organs, which are often the source of annoyance during gestation.

The *functional correlations* or *synergies* are of much more moment to the physiologist and pathologist. Many of these have also been described in the preceding history: a brief notice of them will be all that is now requisite. For the maintenance of the healthy function we know that certain conditions are necessary, and that if these be materially modified, in the whole or in any part of the body, disease and death may be the result, even although the derangement may, in the first instance, concern only an apparently unimportant part of the frame,—the affection, by correlation, spreading gradually to more and more essential organs and functions, until the disorder is ultimately too great to allow of a continuance of the vital movements. In this respect, man differs from an ordinary piece of mechanism, in which the various parts are so adapted to each other as to produce a certain result. If one of these parts be destroyed, the whole machine may have its motion arrested. But the effect is owing to the destruction of one part only, the others remaining sound; whilst death, or the stoppage of the living machine, does not necessarily follow the destruction of any except a few essential organs, and is generally owing to the derangement of many. We shall find, indeed, that except in cases of sudden death, it is extremely difficult to say which of the three truly vital organs has first ceased to act; and that in all such cases death begins in one or other of the organs essential to vitality, and soon extends to the rest.

The essentially vital organs are the respiratory, circulatory, and the organs of innervation; but the great use of respiration is to change the blood from venous to arterial; in other words, to induce a conversion in it by its passage through the lungs, without which it would be inadequate for the maintenance of life in any organ; and the object of the circulation is, to distribute it to the various parts of the frame as the grand vivifying and reparatory material. If, also, the organs of innervation be destroyed, the nervous influence is no longer conveyed to the different parts of the frame; and as the presence of this influence is everywhere indispensable, the functions may cease from this cause; so that we may regard, as essential elements to the existence of the frame and of every part of the frame, the proper supply of arterial blood and of the nervous influence. In the production and distribution, however, of these agencies, a number of functions is concerned, giving rise to the correlation, which is the object of our present inquiry. If, in any manner, the blood does not meet with due aeration, as in the ordinary cases of suffocation, death supervenes, in the order elsewhere described; and if a slight degree of aeration is accomplished, but still not enough for the necessities of the system, instead of suffocation, the individual dies more gradually: the functions fail in the same order; dark blood circulates through all the textures; hence lividity, especially

of those parts where the cuticle is extremely thin, as of the lips, and wherever the mucous membranes commingle with the skin; and the blood gradually becomes inadequate to keep up the action of the brain and nervous system generally, as well as to stimulate the heart, and the individual gradually expires. If, again, the blood, although properly converted in the lungs, is not duly distributed to the organs, owing to the failure of the circulatory powers,—either from direct or indirect causes,—the organs exhibit their correlation in the same manner, and syncope or fainting, or positive death, may be induced. Often, however, the stoppage of the action of the heart is but for a short time. Owing to some painful impression, sudden emotion, or other cause, the organ ceases to contract, either suddenly,—when the person falls down as if deprived of life,—or gradually, when the connexion of the different functions, and the order in which they fail, are manifest. Of this kind of—what the surgeon calls—*morbid sympathy* or *constitutional irritation*, we have a good example in the effect of a trifling operation upon a delicate, and often upon a strong, individual. Bleeding will sometimes induce fainting, both directly, by the abstraction of fluid from the vessels, so that the brain may cease to act; and indirectly, when the quantity removed cannot be presumed to have exerted any influence. Some, indeed, will faint from the slightest puncture and loss of blood, or even from the sight of that fluid. In these last cases, if the syncope come on gradually, a feeling of great anxiety and oppression, occasionally of vacuity, exists in the epigastric region; the perceptions become confused, the sight obscured, tinnitus aurium and dizziness supervene, the respiration is embarrassed, the face pale, the extremities cold, and the different parts of the body are covered with a cold, clammy sweat, until, ultimately, loss of sensation and motion supervenes, and the individual is temporarily dead; from which state he soon recovers, in the generality of cases, provided he be kept in the recumbent posture, so that the blood may readily pass to the brain. On other occasions, the heart will not cease its pulsations, but will continue to send blood, in undue quantity, to the brain, so that all the above symptoms may ensue, except the temporary privation of vitality. In consequence of the severe pain induced by a displacement of two of the bones of the wrist, by a fall from a carriage, the author remained a considerable time incapable of sight, and at the same time suffering from great anxiety, yet consciousness and the action of the heart never ceased, as in complete syncope.

The third vital function,—that of innervation,—when suspended or diminished, draws on a train of pathological phenomena, in the order described under the head of death; suspending respiration and circulation suddenly, if the cause applied be sufficient; more gradually, and with the symptoms characterizing apoplexy or compression of the brain, if the cause act in a minor degree. All the three vital functions are consequently correlative, and so intimately asso-

ciated, that if a malign influence acts upon one, the effect is speedily extended to the other.

Owing to the necessity for the blood possessing certain attributes, the most important of which are obtained by its circulation through the lungs, we can readily understand, that if the functions of nutrition are not properly exerted, the composition of that fluid may be imperfect, and disorder take place in various parts of the frame from this cause. Thus, if digestion or the formation of chyle be not properly executed, the blood is not duly renovated, and may be so far impoverished, that the play of the functions is interfered with. We have elsewhere shown, that if omnivorous man be restricted to one kind of diet he will fall off, and become scorbutic, and the affection will be removed by allowing him diet of another kind;—vegetables, if animal food have induced it, and *vice versa.* Enlarged mesenteric glands, consequent, or not, on inflammation of the mucous membrane of the intestine, and the latter affection itself, are cases which may interfere with chylosis, and consequently with the constitution of the blood. In like manner, if nutrition and the various secretions are not duly performed in the tissue of the organs, and, especially, if the great depurations be obstructed, the blood may suffer, and although the due changes from venous to arterial may be effected in the lungs, its character may not be such as to adapt it for the healthy execution of the various functions.

The humorists assigned too much importance to the condition of the humours in the production of disease; the solidists, on the other hand, have denied it almost all agency. The medium between these exclusionists is probably the nearest to nature. The solitary fact of black blood being unfit to maintain the perfect and continued vitality of any organ sufficiently exhibits its influence. How the arterial blood exerts its agency, independently of its action as a fluid of nutrition, is beyond our knowledge. It appears to effect a necessary action of stimulation, but in what manner, or on what element, we know not: probably, however, its chief influence may be on the nervous tissue, as the privation of arterial blood soon occasions the cessation of the action of the brain.

In the higher classes of animals, innervation is dispensed from three great centres,—the encephalon, the spinal marrow, and the great sympathetic. The presidency, however, may be fairly assigned, in man and in the higher animals, to the first of these. If it fails, death soon becomes general. This, however, is liable to great variation in different animals, and likewise in different functions. In man, if the nervous supply be cut off from any part, the part dies. Physical integrity, continuity, and a due supply of arterial blood, are necessary to the proper exercise of the nervous power. In a former part of this work, the wonderful resistance to death, which characterizes the amphibia, and the comparative independence of each portion of the body, in some of the lower orders of animals, were pointed out. The polypus can be divided into numerous pieces, yet

each may constitute of itself a distinct animal. The snail, after decapitation, reproduces the head; and a similar reparatory power is possessed by other animals. We have elsewhere seen, that volition is seated lower in the inferior than in the superior orders of animals; and that in man it is chiefly,—some say, wholly,—restricted to the encephalon.

It appears, likewise, that the dependence of the rest of the nervous system on the great nervous centres is less in young than in old animals. Edwards regarded the new-born child as resembling, in many respects, the cold-blooded animal, and Redi, Rolando, and Flourens, and Legallois found, that the tenacity of life, after decapitation, was much greater the nearer to birth.

The functions also differ with regard to their dependence upon the encephalon. Disease may attack the animal functions and suspend them for a considerable length of time,—as in apoplexy,—before the organic functions are interfered with. This is a topic, however, which will be discussed under the head of DEATH.

We may conclude, then, that "life," to use the language of a gifted preceptor of the author,—M. Béclard,—"consists essentially in the reciprocal action of the circulation of the blood and innervation; death always following the cessation of such reciprocal action." But this conclusion is applicable only to animals; although both circulation and innervation are admitted in the vegetable by some physiologists. Legallois, from his experiments, deduced the unwarrantable inference, that "life is owing to an impression made by arterial blood on the brain and spinal marrow, or to the principle, which results from this impression;"—a definition, which would exclude the numerous animals of the lower classes, as well as vegetables, which are deficient in both brain and spinal marrow.

The conclusion of Béclard is the limit to our knowledge on this subject. Yet some have endeavoured to discover which of the two functions,—circulation or innervation,—holds the other in domination. They, who consider the nervous substance to be first formed in the fœtus, ascribe the supremacy to it; whilst the believers in the earlier formation of the sanguiferous system look upon it as the prime agent. We know no more than that both

> "Maintain
> With the mysterious mind and breathing mould
> A co-existence and community."

In every important function of the body we find this correlation or catenation of organs existing; all working to one end, and all requisite for its perfect accomplishment. How many organs, for example, are required to co-operate in the elevated function of sensibility! The encephalon, the seat of thought, receives, by the external senses, the various impressions which act upon them from without, and, by the internal sensations, such as arise in the economy, and are gene-

rally the indexes of the physical necessities or wants. The intellectual and affective faculties enable us to appreciate the various objects that occasion our sensations, and indicate our social and moral wants: under their direction, volition is sent out, which acts upon the various muscles, and produces such movements as may be required for carrying into effect the suggestions of the mind. Between all these acts, there is the closest catenation.

In like manner, we observe the correlation between the animal, and the nutritive, and reproductive functions. The internal sensation of hunger suggests to the mind the necessity for a supply of aliment; the external senses are called into action to discover the proper aliment; when discovered, it is laid hold of by muscular movements under the direction of volition, is subjected to various voluntary processes in the mouth, and then passed on, by a mixed voluntary and involuntary action, into the stomach. In like manner, the desire for sexual intercourse may be excited in the mind through the organs of vision or touch; the organs of generation are aroused to action, and the union of the sexes is accomplished by the exertion of muscles thrown into contraction by volition. The same catenation is exhibited after a fecundating copulation: menstruation, which was previously performed with regularity, is now arrested; the breasts become developed; milk is formed in them, and, whilst the female suckles her child, unless the period is unusually protracted, the non-existence of the menstrual function continues.

Almost all the phenomena of disease are connected with this correlation of functions. Derangement takes place in one organ or structure of the body, and speedily all those, that are correlated with it, participate in the disorder. Hence, in part, arises the combination of disordered nervous, circulatory, and secretory function, which characterizes general fever; and the various associated morbid actions that constitute disease in general.

There is another kind of connexion which distinguishes the animal body from a piece of ordinary mechanism yet more than those we have considered. In this, owing to an impression made upon one organ, distant organs become affected, without our being able to refer the transmission to mechanical agency, or to the association of functions which we have just described. This kind of association is called *sympathy*. A particle of snuff or other irritating substance, impinging on the Schneiderian membrane, produces itching there, followed by a powerful action of the whole respiratory apparatus, established for its removal. The sneezing, thus induced, is not caused by the transmission of the irritation through the intermediate organs to the respiratory muscles; nor can we explain it by the mechanical or functional connexions of organs. It is produced by this third mode of correlation:—in other words, it is a case of sympathy.

Again, a small wound in the foot will produce locked jaw, without our being able to discover, or to imagine, any greater con-

nexion between the foot and the jaw than there is between the foot and other organs of the body. We say, that it is caused by sympathy existing between these organs, and, so long as we use the term to signify the unknown cause of these connexions, it is well. It must be understood, however, that we attach no definite idea to the term; that it is only employed to express our ignorance of the agent or its mode of action; precisely as we apply the epithet *vital* to a process, which we are incapable of explaining by any physical facts or arguments.

Of sympathetic connexions, we have numerous examples in the body; at times, inservient to accomplishing a particular function; but generally consisting of modifications of function produced by the action of a distant organ. Of the sympathetic connexion between the parts of the same organ, for the execution of a function proper to the organ, we have an example in that between the iris and the retina; the former will contract or dilate according to the degree of stimulation exerted by the light on the latter; and the effect is greater when the light is thrown on the retina than when thrown on the iris itself.

A similar kind of sympathy exists between the state of the mammæ and that of the uterus, during pregnancy; although this has been frequently referred to ordinary functional correlation or synergy; but the connexion is sufficiently obscure to entitle it to be placed under this division. A singular example of the sympathy between these two organs, soon after delivery, is the fact of the sudden and powerful contraction which is excited in the uterus, when in a state of inertness, by the application of the child to the breast.

Sympathies of continuity are such as occur between various parts of membranes that are continuous. For example, the slightest taste or smell of a nauseous substance will bring on an effort to vomit,—the whole of the first passages being unfavourably disposed for its reception. In disease, we have many examples of this kind of sympathy. During dentition the child is subject to various gastric and intestinal affections. If a source of irritation exist in any part of the intestinal or other mucous membrane, no uneasy sensation may be experienced in the seat of irritation, yet it may be felt at the commencement of the membrane or where it commingles with the skin:—thus, itching at the nose may indicate irritation of the digestive mucous membrane;—itching or pain of the glans penis, stone in the bladder, &c. These facts prove, that, in disease, a sympathetic bond unites the parts concerned, and such is probably the case in health also. We have the same thing proved in the effect produced on the action of glands by irritating the orifices of their excretory ducts. The presence of food in the mouth excites the secretion of the salivary glands, and that of chyme in the duodenum augments the secretion of the liver. In the same manner, a purgative, as calomel, which acts upon the upper part of the intestinal

canal, becomes a cholagogue; and duodenitis occasions a copious biliary secretion. These cases, have, however, been considered by many, to belong more appropriately to functional correlation, as it is presumable, that the propagation of the irritation from the orifice of the excretory duct takes place directly, and along branches of the same nerves as those that supply the glandular organs. It is by this sympathy of continuity that we explain the action of certain medicines. In bronchial irritation, for example, the cough will frequently be mitigated by smearing the top of the larynx by a demulcent,—the soothing influence of which extends to the part irritated.

A variety of sympathy, differing somewhat from this, is the *sympathy of contiguity* or *contiguous sympathy*, in which an organ is affected by an irritation seated in another immediately contiguous to it. The association in action, between the lining membrane of the heart and the muscular tissue of the organ, has been adduced as an instance of this kind, and chiefly from the experiments of Bichat and Nysten, which showed, that any direct irritation of the muscular tissue of the heart has not as much influence as that of the membrane which lines it. A similar association is presumed to exist between the mucous and muscular coats of the alimentary canal, and the same kind of evidence is adduced to prove that the connexion is sympathetic.

Other instances of sympathy are,—the convulsive contraction of the diaphragm and abdominal muscles in vomiting consequent on condition of the stomach, as well as the convulsive action of the respiratory muscles in sneezing, coughing, &c. The general uniformity in the motion of the two eyes has been adduced as an additional instance; but Adelon has judiciously remarked, that the evidence in favour of this view is insufficient. For clearness of vision it is necessary, that the luminous rays should impinge upon corresponding points of the two retinæ, and should fall as nearly as possible in the direction of the optic axes. For this purpose, the muscles direct the eyes in the proper manner; and subsequently, from habit, the balls move in harmony. We constantly hear, also, a fact adduced from pathology as an instance of sympathy. A molar tooth is lost on one side of the jaw; and it is found, perhaps, that the next tooth, which decays is the corresponding molar tooth of the opposite side:—or a tooth has become carious, and we find the one next to it soon afterwards in a course of decay. These have been regarded as evidences of sympathy,—remote and contiguous. This is not probable. The corresponding teeth of the two sides are similarly situated as regards the supply of nerves, vessels, and every anatomical element; and experience teaches us, that the molar teeth—and especially the second great molares—decay sooner than the others. If one, therefore, becomes carious, we can understand, why its fellow of the opposite side should be more likely to suffer. The opinion, that contiguous teeth are likely to be affected by the presence of a carious tooth, either by sympathy, or by direct contact, is almost

universally believed, and promulgated by the dentist. Both views are probably alike erroneous. If the inner side of the second molaris be decayed, we can understand, why the corresponding side of the third should become carious, without having recourse either to the mysterious agency of sympathy, or to the very doubtful hypothesis of communication by contact,—especially as the caries generally begins internally. The contiguous sides of the teeth are situated almost identically, as regards their anatomical elements; and, consequently, if a morbid cause affects the one, the other is the next likely to suffer, and is very apt to do so. Extracting the diseased tooth prevents this, because it removes a source of irritation, which could not but act in a manner directly injurious on the discharge of the functions of the tooth next to it.

The fact of the sympathy,which exists between organs of analogous structure and functions, is familiar to every pathologist. That of the skin and mucous membranes is the most intimate. In every exanthematous disease, the danger is more or less dependant upon the degree of affection of the mucous membranes; and the direct rays of the sun, beaming upon the body in warm climates, induce diarrhœa and dysentery. Acute rheumatism is a disease of the fibrous structures of the joints; but one of its most serious extensions, or metastases, whichsoever they may be called, is to the fibrous structure of the pericardium. Barthez, a most respectable writer, gives a case of this kind of sympathy from Theden which is inexplicable, and incredible. A patient, affected with paralysis of the right arm, applied a blister to it, which produced no effect, but acted on the corresponding part of the other arm. The left becoming afterwards paralyzed, a blister was put upon it, which also acted upon the other arm, not on the one to which it was applied!

Owing to this sympathy or consent of parts, Broussais has laid down the pathological law,—that when an irritation exists for a long time in an organ, the textures that are analogous to the one, which is diseased, are apt to contract the same affections.

As examples of the more distant kinds of sympathies, we may cite the effect produced upon the stomach by distant organs, and conversely. Amongst the earliest signs of pregnancy are nausea, and vomiting; loathing of food; fastidious appetite, &c. These symptoms are manifestly induced by sympathetic connexion between the uterus and stomach; inasmuch as they are not adventitious, but occur more or less in all cases of pregnancy. Their absence, at least, is a rare exception to the rule. Hunger or dyspepsia, again, impresses a degree of languor,—mental and corporeal,—which is proverbial; whilst the reception of food and its vigorous digestion give a character of energy, and buoyancy, greatly contrasting with opposite circumstances. In disease, too, we find sympathies existing between the most distant portions of the frame, and although these are not apparent to us in health, we are perhaps justified in considering that an occult sympathy exists between them in health,

which only becomes largely developed, and obvious to us, when the parts are affected with disease. It is probable, too, that in the successive evolution of organs at different periods of life, new sympathies arise, which did not previously exist or were not observable. The changes, that supervene in the whole economy at puberty, strikingly illustrate this;—changes which do not occur in those, who, owing to malformation, are not possessed of the essential parts of the reproductive system, or who have had them abstracted prior to this period.

The effect of the intellectual and moral faculties on the exercise of the functions of other parts is strongly evidenced, especially in disease. The influence of the mind over the body is, indeed, a subject which demands the attention of every pathologist. In health, we notice the powerful effect induced by the affective faculties upon every function. All these are caused by sympathetic association with the brain; the action of the organs being in a state of excitation or depression, according to the precise character of the emotion. The intellectual manifestations probably exert their influence in a manner less evident, but not the less certain. The effects of one of them, at least, on the bodily functions are remarkable. We allude to the *imagination;* to which we can ascribe most of the cures that are said to have been effected by modes of management,—often of the most disgusting character,—which have been from time to time in vogue, have fretted their hour on the stage, and then sunk into that insignificance from which they ought never to have emerged.

We have had occasion to allude to the excited imagination of the maniac, the hypochondriac, and the nervous, and have remarked, that hallucinations may exist in those of sound mind;—phantoms created by the imagination; pains felt in various bodily organs, &c.; and we can hence understand, that, under particular circumstances, we may have actual disease produced in this manner; and, at other times, the feeling,—which may be as distressing to the patient,—of disease, which has no existence except in the imagination. It is to the effect produced by the imagination, that we must ascribe the introduction into medicine of magic, sorcery, incantations, Perkinism, Mesmerism, and other offsprings of superstition or knavery. The enthusiasm, that has attended the application of these last modes of acting upon the imagination in our own times, is most extraordinary.

The history of these operations leads us to be still more impressed with the extensive influence that may be exerted by the mind over the body: they teach the practitioner the importance of having its co-operation, whenever it can be procured; and the disadvantages, which he may expect to ensue, where the imagination is either arrayed against himself personally, or the plan of treatment which he is adopting. The physician, who has the confidence of his patient, will be successful—if he adopt precisely the same plan of treatment that would be pursued by one who has it not—in cases where the

latter would total fail. The applications of this subject will be developed in the author's forthcoming work on "General Therapeuteis."

Again, pathology is invoked as affording us perhaps the best evidences of the existence of extensive sympathetic relations between various parts of the frame, which are supposed to be constantly going on unseen during health, but become developed, and more obvious in disease. The case, we have previously given, of the general effects produced upon the system by local irritation of a part, shows the extent of such association. An insignificant portion of the body may become inflamed, and, if the inflammation continues, the function of the stomach may be disordered,—as indicated by loss of appetite, nausea and vomiting; the respiration hurried, as well as the circulation; the senses blunted; the intellectual and moral faculties obscured; and languor and lassitude may indicate the nervous irritation and constraint.

The moral consideration of sympathy does not concern us. It is a subject,—and one of interest to the moral philosopher,—to account not only for these secret causes, which attract individuals towards each other, but which repel them, and occasion *antipathies.* To a certain extent, however, it trends into the province of the physiologist. The tender, susceptible individual, from observing another suffering under pain, feels as if labouring under the same inconvenience, and, by a very rapid, yet complex, intellectual process, constituted of numerous associations, may be so strongly impressed as to sink under their influence;—thus, the sight of blood will so powerfully impress the mind, in this sympathetic manner that the individual may faint, and the vital functions be for a time suspended. The sight and suffering of a woman in labour may cause abortion in another; and hence the propriety of excluding those, who are pregnant, from the chamber of the parturient female. Hysteric and convulsive paroxysms are induced in a similar way; of which the *convulsionnaires* of all times must be regarded as affording singular and instructive examples.

Lastly; the mysterious consent, which we observe between various parts of the body, has given rise to some of the most strange and absurd superstitions that can be imagined. It was believed, for instance, almost universally in the fifteenth century, that an intimate sympathy exists, not only between parts of a body forming portions of one whole, but also between any substance that had previously formed part of a body and the body itself: that if, for example, a piece of flesh were sliced from the arm of one person and made to unite to that of another, the grafted portion would accurately sympathize with the body of which it had previously formed part, and undergo decay and death along with it; and it was even proposed to turn this sympathy to account. It was recommended, for instance, that the alphabet should be traced on the ingrafted portion; and it was affirmed, that when any of the letters, so traced, were touched, the party from whom the piece of flesh had been taken would feel

similar impressions; so that, in this manner, a correspondence might be maintained.

Some went even farther than this, asserting, that such a miraculous sympathy exists between the human body and all that has previously formed part of it, that if we were to run a hot iron into the excrement of any person, he would feel a sensation of burning in the part, whence it had proceeded.

It was also a notion that grafts of flesh, united to another body, die when the person dies from whom they have been taken. In a recent work on animal magnetism, the case of a man at Brussels is given, who had an artificial nose, formed after the old Taliacotian method, which served every useful purpose until the person, from whom the graft had been taken, died, when it suddenly became cold and livid and finally fell off. Tagliacozzi himself lived in an era of superstition, when this belief in the synchronous death of the parent and graft was universally credited; and the folly has not escaped the notice of Butler:—

> "So learned Taliacotius from
> The brawny part of porter's bum,
> Cut supplemental noses which
> Would last as long as parent breech;
> But when the date of nock was out,
> Oft dropped the sympathetic snout."

Little less singular was the superstition,—that the wounds of a murdered person will bleed afresh, if the body be touched, ever so lightly in any part, by the murderer. This idea gave rise to the trial by *bier-right*, which has been worked up by Sir Walter Scott with so much dramatic skill, in one of his more recent novels—*St. Valentine's Day, or the Fair Maid of Perth.* The annals of judicial inquiry furnish us with many instances of this gross superstition, which still exists amongst the lower orders in some parts of Great Britain, and probably also amongst the credulous and uninformed of this country.

In the year 1688, a gentleman, of the name of Stansfield, was tried at Edinburgh for the murder of his father—Sir Philip Stansfield—and found guilty. The indictment in this case, amongst other things, states, "that his nearest relations being required to lift the corpse into the coffin after it had been inspected; upon the said Philip Stansfield touching of it ('according to God's usual method of discovering murder,' says the framer of the indictment) it bled afresh upon the said Philip, and that thereupon he let the body fall, and fled from it in the greatest consternation; crying,—Lord, have mercy upon me!" On this portion of the indictment, the King's advocate remarked:—"That as to the body bleeding, although several persons touched it, none of their hands were besmeared with blood but the prisoner's; and that the body having lain two days in the grave, in a cold season, the blood must naturally be congealed. That the lifting about

the body, and even the incision that was made, causing no such effusion before, but only of some water or gore, and should upon the prisoner's first touching it begin to bleed afresh! he must ascribe it to the wonderful providence of God, who, in this manner, discovers murder, especially since no natural reason could be assigned for it; and that the horrible impressions it made on the prisoner, notwithstanding his resolution to the contrary, might be urged as another argument of his guilt."

A case of a similar character is given in the *Annual Register* for 1767, as having occurred in our own country. It is contained in the attestation of John Demarest, coroner of Bergen county, New Jersey. The superstition, too, is noticed by many of the older poets. Thus, Shakespeare, in his *Richard III.*—where the Lady Anne reviles Gloster over the corpse of Henry:—

"O! gentlemen, see, see! dead Henry's wounds
Open their congeal'd mouths, and bleed afresh!
Blush, blush, thou lump of foul deformity;
For 'tis thy presence that exhales this blood
From cold and empty veins, where no blood dwells.
Thy deed, inhuman and unnatural,
Provokes this deluge most unnatural."

And Webster, in his tragedy of *Appius and Virginia*, published about the middle of the seventeenth century:—

"See
Her wounds still bleeding at the horrid presence
Of yon stern murderer, till she find revenge."

The belief in these cases of monstrous superstition, which, it need scarcely be said, are usually explicable on purely physical principles, or on the excited imagination of the observer, still exists amongst the benighted inhabitants of many parts of Great Britain and Ireland, and is the main topic of one of the second series of "Traits and Stories of the Irish Peasantry." The superstition, has, indeed, its believers among us. On the trial of Getter, who was executed about two years age (1833) in Pennsylvania, for the murder of his wife, a female witness deposed on oath, as follows:—"If my throat was to be cut, I could tell, before God Almighty, that the deceased smiled, when he (the murderer) touched her. I swore this before the justices, and that she bled considerably. I was sent for to dress her and lay her out. He touched her twice. He made no hesitation about doing it. I also swore before the justice, that it was observed by other people in the house."

It would be endless to enumerate the various superstitions, which prevailed, a few centuries ago, on topics more or less remotely connected with this subject. We pass on, therefore, to the interesting, but abstruse, inquiry into the agents by which sympathy is accomplished.

The opinions of physiologists have, from time to time, rested chiefly;—on the membranes, the cellular tissue, the blood-vessels, and the nerves; whilst there have been some, who, in the difficulty of the subject, have supposed sympathy to be devoid of all organic connexion; and others, again, have presumed, that all the parts, we have mentioned, are concerned. The rapidity, however, with which sympathies are evidenced, has led to the abandonment of all those opinions; and the generality of physiologists of the present day look to the nervous system as the great source and medium of communication of the different irradiations, by which distant organs are supposed to react, in this manner, upon each other. The rapidity, indeed, with which the various actions of the nervous system are executed,—the apparent synchronism between the reception of an impression on an organ of sense, and its perception by the brain, as well as between the determination of the will and its effect upon a muscle,—naturally attracted the attention of physiologists to this system as the instrument of sympathy.

The modes, in which it is supposed to be accomplished, are:—either by the parts, that sympathize, receiving ramifications from the same nervous trunks, or from such as are united by nervous anastomosis; or, by the nervous irradiation emanating from one organ, proceeding to the brain, and being thence reflected to every dependency of the system, but so that certain organs are more modified by such reflection than others; hence, the distinction into what have been termed *direct sympathies* and *cerebral sympathies.*

Of the direct sympathies we have already given some examples,—as that between the mucous and muscular coats of the intestines; and if our acquaintance with the precise distribution and connexion of the various parts of the nervous system were more intimate, we might perhaps explain many of the cases that are yet quite obscure to us. The researches of Sir Charles Bell, regarding the nerves concerned in respiration, have thrown light on those associations of organs, which we notice in the active exercise of the respiratory function. It has been elsewhere shown that although the whole of the nerves, composing his *respiratory system*, may not be apparently in action during ordinary respiration, yet that when the function has been greatly excited, the association becomes obvious; parts, that are remote in situation, are combined in function, and all the nerves that animate them, he conceives, arise from the same column of the spine. The opinion of Boerhaave, Meckel, and some others is, that all sympathies are accomplished in this direct manner. On the other hand, Haller, Whytt, Georget, Broussais, Adelon, and others, make the majority of sympathies to be produced through the medium of the brain. Bostock indeed affirms, that the facts, adduced by Whytt, are of such a nature as "to prove, that the co-operation of the brain is essential in those actions, which we refer to the operation of sympathy." In many cases, this is doubtless the fact;—as in sneezing and coughing; but there are others in which such co-operation seems

improbable and indeed impossible. Something like sympathy exists in the vegetable; in which if we admit, with some naturalists, a rudimental nervous system, we have no reason for presuming that there is anything like a centre for the reception or transmission of impressions, and the case of infants, born devoid of brain and spinal cord, affords evidence of a like description.

We find, that the properties of the vital principle are exemplified by the formation of a body of a certain magnitude, form, structure, composition and duration, and that this applies to all organized bodies, vegetable as well as animal. Where such appearance of design, consequently, exists, we ought to expect, that in the vegetable, also, a harmony or consent must reign amongst the various functions, tending to the accomplishment of that uniformity, which enables us always to recognize the particular varieties of the vegetable kingdom, and which has kept them as distinct, probably, in their characters, as when first created by Almighty power. The irritation of a single leaflet of the *Mimosa pudica* or *sensitive plant* causes the whole leaf, as well as the footstalk, to contract. Dr. John Sims irritated a leaflet of this plant, taking the greatest pains to avoid moving any other part of the leaf; yet the whole contracted, and the footstalk dropped. In order, however, to be sure, that mechanical motion, communicated by the irritation, had no share in the contraction, he directed a sunbeam, concentrated by a lens, on one of the leaflets, when the leaf again contracted, and the footstalk dropped. Of this kind of vegetable irritability we have many examples, some of which are alluded to under another head.

From these, and other facts of an analogous character, Sir Gilbert Blane concludes, that the functions of living nature, in all its departments, are kept up by a mutual concert and correspondent accordance of every part with every other part, and that it would be in vain to waste time in endeavouring to account for them by groping among dark analogies and conjectures; and that it is better to assume them as facts, on which are founded the ultimate and inscrutable principles of the animal economy. We have, certainly, much to learn regarding the agents of sympathies, and the modes in which they are operated; but still we know enough to infer, that in many cases, in animals, the nerves appear to be the conductors; that the brain is, in others, the centre to which the organ in action transmits its irradiations, and by which they are reflected to the sympathizing organ; and that, in others, again, the effect is caused in the absence of nervous centre, and even of nerves, by vibrations, perhaps, but in a manner, which, in the present state of our knowledge, is inexplicable, and is, therefore, supposed to be essentially *organic* and *vital*,—epithets, however, as we have more than once expressed, that merely convey a confession of our total ignorance of the processes to which they are appropriated.

OF INDIVIDUAL DIFFERENCES AMONGST MANKIND.

The differences, which we observe amongst the individuals of the great human family, are as numerous as the individuals themselves; but this dissimilarity is not confined to man or to the animal kingdom; the vegetable exhibits the same; for, whilst we can readily refer any plant to the species and variety, to which it may have been assigned by the botanist, accurate inspection shows us, that, in the precise arrangement of the stalk, branches, leaves, or flowers, no two are exactly alike. We shall not, however, dwell on these trifling points of difference, but restrict ourselves to the broad lines of distinction, that can be easily observed, and an attention to which is of some moment to the physician. Such are the *temperaments*, *constitutions*, *idiosyncrasies*, *acquired differences*, and the *varieties of the human species* or the *different races of mankind.* Of these, the last belongs more especially to the natural historian, and, consequently, will be but briefly noticed.

Sect. I. Of the Temperaments.

The temperaments are defined to be,—those individual differences, which consist in such disproportion of parts, as regards volume and activity, as to sensibly modify the whole organism, but without interfering with the health. The temperament is, consequently, a physiological condition, in which the action of the different functions is so *tempered* as to communicate certain characteristics, which may be referable to one of a few divisions. These divisions are by no means the same in all physiological treatises. The ancients generally admitted four,—denominated from the respective fluids or humours, the superabundance of which in the economy was supposed to produce them;—the *sanguineous*, caused by a surplus of blood; the *bilious* or *choleric*, produced by a surplus of yellow bile; the *phlegmatic*, caused by a surplus of phlegm, lymph, or fine watery fluid, derived from the brain; and the *atrabiliary* or *melancholic*, produced by a surplus of black bile,—the supposed secretion of the atrabiliary capsules and spleen.

The division was continued for ages without modification, and still prevails, with one or more additional genera. The epithets have been retained in popular language without our being aware of their parentage. For example, we speak of a *sanguine*, *choleric*, *phlegmatic*, or *melancholic* individual or turn of mind, with precisely the acceptation given to them by the Hippocratic school,—the possessors of these temperaments being presumed to be, respectively,

full of high hope and buoyancy; naturally irascible, dull and sluggish; or gloomy and low-spirited. Metzger admits only two,—the *irritable*, (reizbare,) and the *dull* or *phlegmatic*, (träge.) Wrisberg eight,—the *sanguine*, *sanguineo-choleric*, *choleric*, *hypochondriac*, *melancholic*, *bœotian*, *meek*, (sanftmüthige,) and the *dull* or *phlegmatic*. Rudolphi also eight,—the *strong* or *normal*, the *rude*, *athletic* or *bœotian*, the *lively*, the *restless*, the *meek*, the *phlegmatic* or *dull*, the *timorous*, and the *melancholic*;—whilst Broussais enumerates the *gastric*, *bilious*, *sanguine*, *lymphatico-sanguineous*, *anemic*, *nervous*, *bilioso-sanguine*, *nervoso-sanguine*, and *melancholic*.

It is obvious, that if we were to apply an epithet to the possible modifications, caused by every apparatus of organs, the number might be extended much beyond any of these. Perhaps, the division, most generally adopted, is that embraced by Richerand, who has embodied considerable animation, with much that is fanciful, in his description. In this division, the ancient terms have been retained, whilst the erroneous physiological basis, on which they rested, has been discarded. A short account of these temperaments is necessary, rather for the purpose of exhibiting what has been, and is still, thought by many physiologists, than for attesting the reality of many of the notions that are mixed up with the subject. With this view, the temperaments may be divided into the *sanguine*, the *bilious* or *choleric*, the *melancholic*, the *phlegmatic*, and the *nervous*.

1. The *sanguine temperament*. This is supposed to be dependent upon a predominance of the circulatory system; and hence is considered to be characterized by strong, frequent, and regular pulse; ruddy complexion; animated countenance; good shape, although distinctly marked; firm flesh; light hair; fair skin; blue eyes; great nervous susceptibility, attended with rapid *successibilité*, as the French term it; that is,—facility of being impressed by external objects, and of passing rapidly from one idea to another; quick conception; ready memory; lively imagination; addiction to the pleasures of the table; and amorousness. The diseases of the temperament are generally violent; and are chiefly seated in the circulatory system,—as fevers, inflammations und hemorrhages.

The physical traits of this temperament, according to Richerand, are to be found in the statues of Antinous and the Apollo Belvidere: the moral physiognomy is depicted in the lives of Mark Antony and Alcibiades. In Bacchus, both the forms and the character are found; and no one, in modern times, in M. Richerand's opinion, can be found to exhibit a more perfect model of it than the celebrated Duke De Richelieu;—amiable, fortunate and valorous, but light and inconstant to the termination of his brilliant career.

If individuals of this temperament apply themselves to labours of any kind, that cause the muscles to be greatly exerted, these organs become largely developed, and a subdivision of the sanguine

temperament is formed, which has been called the *muscular* or *athletic*. This is characterized by all the outward signs of strength; the head is small; the neck strong; the shoulders broad; the chest large; the hips solid; the muscles prominent, and the interstices well marked. The joints, and parts not covered with muscles, seem small; and the tendons are easily distinguished through the skin, by their prominence. The susceptibility to external impressions is not great; the individual is not easily roused; but, when he is, he is almost indomitable. A combination of the physical powers, implied by this temperament, with strong intellect, is rarely met with.

The Farnesian Hercules is conceived to offer one of the best specimens of the physical attributes of the athletic temperament.

2. The *bilious* or *choleric temperament.* This is presumed to be produced by a predominance of the liver and biliary organs in general. The pulse is strong, hard, and frequent; the subcutaneous veins are prominent; the skin is of a brown colour, inclining to yellow; hair dark; body moderately fleshy; muscles firm, and well-marked; the passions violent, and easily excited; the temper abrupt, and impetuous; great firmness and inflexibility of character; boldness in the conception of projects, and untiring perseverance in their fulfilment. It is amongst the possessors of this temperament, that the greatest virtues and the greatest crimes are met with. Richerand enumerates Alexander, Julius Cæsar, Brutus, Mahomet, Charles XII., Peter the Great, Cromwell, Sextus V., and the Cardinal Richelieu. To these Good has added, Attila, Charlemagne, Tamerlane, Richard III., Nadir Shah, and Napoleon.

The moral faculties are early developed; so that vast enterprises may be conceived, and executed at an age when the mind is ordinarily far from being matured. The diseases are generally combined with more or less derangement of the hepatic system. The whole of the characters, however, indicate, that an excited state of the sanguiferous system accompanies that of the biliary organs; so that the epithet—*cholerico-sanguine*—might, with more propriety, be applied to it. Where this vascular predominance does not exist, whilst derangement is present in some of the abdominal organs, or in the nervous system, we have the next genus produced.

3. *Melancholic* or *atrabilious temperament.* Here the vital functions are feebly or irregularly performed; the skin assumes a deeper hue; the countenance is sallow and sad; the bowels are torpid, and all the excretions tardy; the pulse is hard and habitually contracted; the imagination is gloomy, and the temper suspicious. The characters of Tiberius and of Louis XI., are considered to be instances of the predominance of this temperament; and, in addition to these, Richerand has enumerated Tasso, Pascal, Gilbert, Zimmermann, and Jean-Jacques Rousseau.

4. The *phlegmatic*, *lymphatic* or *pituitous temperament.* In this case, the proportion of the fluids is conceived to be too great for that of the solids; the secretory system appearing to be active, whilst

the absorbent system does not act so energetically as to prevent the cellular texture from being filled with the humours. The characteristics of this temperament are:—soft flesh; pale skin; fair hair; weak, slow and soft pulse; figure rounded, but inexpressive; the vital actions more or less languid; the memory by no means tenacious, and the attention vacillating; with aversion to both mental and corporeal exertion.

Pomponius Atticus—the friend of Cicero—is offered as an example of this temperament, in ancient times; Montaigne, in more recent history. The latter, however, possessed much of the nervous susceptibility that characterizes the more lively temperaments. Dr. Good suggests the Emperor Theodosius as an example in earlier times; and Charles IV. of Spain, who resigned himself almost wholly into the hands of Godoy,—Augustus, King of Saxony, who equally resigned himself into the hands of Napoleon,—and Ferdinand of Sicily, who surrendered for a time the government of his people to the British,—as instances in our own day. It would not be difficult to find, amongst the crowned heads of Europe, others that are equally entitled to be placed amongst these worthies.

5. The *nervous temperament.* Here the nervous system is greatly predominant; the susceptibility to excitement from external impressions being unusually developed. Like the melancholic temperament, this is, however, seldom natural or primitive. It is morbid or secondary, being induced by sedentary life, sexual indulgence, or morbid excitement of the imagination, from any cause. It is characterized by small, soft, and, as it were, wasted muscles; and generally, although not always, by a slender form; great vividness of sensation; and promptitude and fickleness of resolution and judgment. This temperament is frequently combined with some of the others. The diseases, that are chiefly incident to it, are of the hysterical and convulsive kind; or those to which the epithet *nervous* is usually appropriated. Voltaire, and Frederic the Great are given by Richerand as examples of this temperament.

Such are the temperaments, described by most writers. The slightest attention to their reputed characteristics will show the imperfection of their definition and demarcation; so imperfect, indeed, are they, that it is extremely rare for us to meet with an individual, whom we could unhesitatingly refer to any one of them. They are also susceptible of important modifications by climate, education, &c., and may be so combined as to constitute innumerable shades. The man of the strongest sanguine characteristics may, by misfortune, assume all those that are looked upon as the indexes of the melancholic or atrabilious; and the activity and impetuosity of the bilious temperament, may, by slothful indulgence, be converted into the lymphatic or phlegmatic. It is doubtful, and more than doubtful, also, whether any of the mental characteristics, assigned to the temperaments, are dependent upon them. The brain, we have elsewhere seen, is the

organ of the mental and moral manifestations; and although we may look upon the temperaments as capable of modifying its activity, they cannot probably affect the degree of perfection of the intellect;—its strength being altogether dependent upon cerebral conformation. It is even doubtful whether the temperaments can interfere with the activity of the cerebral functions. In disease of the hepatic, gastric or other vicera we certainly see a degree of mental depression and diminished power of the whole nervous system; but this is the effect of a morbid condition, and continues only so long as such morbid condition endures. Nor is it probable, that any predominance of the nutritive functions could induce a permanent influence on the cerebral manifestations. Whatever might be the effect for a while, the nervous system would ultimately resume the ordinary action which befitted its primitive organization. Similar reasons to those have induced the author's late friend, M. Georget, —a young physician of great promise and experience in mental affections, now no more,—to consider the whole doctrine of the temperaments as a superstition connected with the humoral pathology, and to believe, that the brain alone, amongst the organs, has the power, by reason of its predominance or inferiority, to modify the whole economy.

That a difference of organization exists in different individuals is obvious; but that there is an arrangement of the nutritive organs or apparatuses, which impresses upon individuals all those mental and other modifications known under the name of temperaments, is, we think, sufficiently doubtful. The *constitution* of an individual is the mode of organization proper to him. A man, for example, is said to have a robust, or a delicate, or a good, or a bad constitution, when he is apparently strong or feeble, usually in good health, or liable to frequent attacks of disease. The varieties in constitution are, therefore, as numerous as the individuals themselves. A strong constitution is considered to be dependent upon the due developement of the principal organs of the body, on a happy proportion between those organs, and on a fit state of energy of the nervous system; whilst the feeble or weak constitution results from a want of these postulates. Our knowledge, however, of these topics, is extremely limited, and concerns the pathologist more than the physiologist.

Sect. II.—Of Idiosyncrasy.

The word *idiosyncrasy* is used, by many physiologists, synonymously with constitution; but it is generally appropriated to the peculiar disposition, which causes an individual to be affected by extraneous bodies, in a way in which mankind in general are not acted upon by the same agents.

> "Some love not a gaping pig—
> And others, when the bagpipe sings i' th' nose,
> Cannot contain their urine for affection." SHAKESPEARE.

In all cases, perhaps, these peculiarities are dependent upon inappreciable structure, either of the organ concerned, or in the nervous branches distributed to it; at times, derived from progenitors; at others acquired,—often by association,—in the course of existence. Hence arise many of the antipathies to particular animate and inanimate objects, which we occasionally meet with, and of which Broussais relates a singular instance in a Prussian captain, whom he saw at Paris in 1815. He could not bear the sight of a cat, a thimble, or an old woman, without becoming convulsed, and making frightful grimaces. The associations must have been singularly complicated to occasion an antipathy to objects differing so signally from each other.

Wagner, of Vienna, has collected a multitude of cases of idiosyncrasy; and the observation of every individual, whether of the medical profession or not, must have made him acquainted with those peculiarities, that render a particular article of diet, which is innoxious, and even agreeable and wholesome to the generality of individuals, productive, in some, of the most unpleasant effects. Haller knew a person who was always violently purged by the syrup of roses. A friend of the author is purged by opium, which has an opposite effect on the generality of individuals. Dr. Paris says he knew two cases, in which the odour of ipecacuanha always produced most distressing dyspnœa. The author knew a young apothecary, who could never powder this drug without the supervention of the most violent catarrh. A friend of Tissot could not take sugar without its exciting violent vomiting. Urticaria or nettle-rash is very frequently occasioned, in particular constitutions, by taking shell-fish. The same effect is induced on two young female friends of the author, by eating strawberries; and similar cases are given by Roose. M. Chevalier relates the case of a lady, who could not take powdered rhubarb without an erysipelatous efflorescence showing itself, almost immediately, on the skin; yet she could take it in the form of infusion with perfect impunity.

The above idiosyncracies apply only to the digestive function. We find equal anomalies in that of the circulation. In some, the pulse is remarkably quick, upwards of one hundred in the minute; in others, it is under thirty. That of Napoleon is said to have beaten only forty-four times in a minute. It may also be unequal, and intermittent, and yet the individual be in a state of health.

The senses offer us some of the most striking cases of this kind of peculiarity. Many strong individuals cannot bear the smell of the apple, cherry, strawberry, or that of musk, peppermint, &c. Pope Pius VII. had such an antipathy to musk, that, on one occasion of presentation, an individual of the company having been scented with it, his holiness was obliged to dismiss the party almost immediately.

The idiosyncrasies of taste are also numerous: some of these cases of singular and depraved sense we have described under the

sense of taste. Dejean gives the case of an individual of distinguished rank who was fond of eating excrement.

Certain animals, again, as the turkey, have an antipathy to the colour of red; and Von Büchner and Tissot cite the case of a boy who was subject to epileptic fits whenever he saw anything of a red colour.

Occasionally, we meet with similar idiosyncrasies of audition. Sauvages relates the case of a young man, labouring under intense head-ache and fever, which could not be assuaged by any other means than the sound of the drum. Rousseau asserts, that a young Gascon was affected with incontinence of urine whenever he heard the sound of the bagpipe; and the noise of water issuing from a pipe threw Bayle into convulsions. The author has a singular peculiarity of this kind, derived from some accidental association in early life. If a piece of thin biscuit be broken in his presence,—nay, the idea alone is sufficient,—the muscles that raise the left angle of the mouth, are contracted, and this irresistibly.

The sense of tact is not free from idiosyncrasies. Wagner cites the case of a person, who felt a sensation of cold along the back, whenever he touched the down of a peach with the point of his finger; or when the down came in contact with any part of his skin. He was remarkably fond of the fruit, yet was unable to indulge his appetite unless a second person previously removed the skin. Prochaska relates the case of a person, who was affected with nausea whenever he touched this fruit.

It is, of course, all important that the practitioner should be acquainted with these idiosyncrasies, and so far the notion of "knowing the constitution,"—which is apt to be used to the prejudice of the young practitioner or of any except the accustomed medical attendant,—has some reason in it. It is the duty, however, of the patient to put the practitioner in possession of the fact of such peculiarities, so that he may be enabled to guard against them, and not take that for morbid which is the effect of simple idiosyncrasy. This, however, is a topic, which belongs rather to therapeutics.

Sect. III. Of Natural and Acquired Differences.

The temperaments, constitutions, and idiosyncrasies may, as we have seen, either be dependent upon original conformation, or they may be produced by external influences; hence they have been divided into the *natural* and *acquired*. Under the former head are included all those individual differences, derived from progenitors, which impress upon the individual, more or less of resemblance to one or both parents. It has been properly observed by a recent writer, that the individuality of any human being that ever existed was absolutely dependent on the union of one particular man with one particular woman; and if either the husband or the wife had been different, a different being would have been ushered into exist-

ence. For the production of Shakespeare, or Milton, or Newton, it was necessary, that the father should marry the identical woman he did marry. If he had selected any other wife, there would have been no Shakespeare, no Milton, no Newton. Sons might have been born of other women, but they would not have been the same, either in mental or physical qualities. All this, however, enters into the question of the influence of both parents on the fœtus in utero, which we have considered elsewhere.

Amongst the natural differences, those that relate to *sex* are the most striking. In a previous part of this volume we have described the peculiarities of the sexual functions in both male and female, but other important differences have not been detailed. All the descriptions, when not otherwise specified, were presumed to apply to the adult male. At present, it will be only necessary to advert to the peculiarities of the female.

The stature of the female is somewhat less than that of the male, the difference being estimated at about a twelfth. The chief parts of the body have not the same mutual proportions. The head is smaller and rounder; the face shorter; the trunk longer, especially the lumbar portion, and the chest more convex. The lower extremities, especially the thighs, are shorter, so that the half of the body does not fall about the pubes, as in man, but higher. The neck is longer; the abdomen is broader, larger, and more prominent; the pelvis has a greater capacity to adapt it for gestation and parturition. The long diameter of the brim is from side to side, whilst, in the male, it is from before to behind; the arch of the pubis is larger, and the tuberosities of the ischia more widely separated, so that the outlet of the pelvis is larger than in the male; the hips are broader, and, consequently, the spaces between the heads of the thigh-bone are greater; the knees are more turned in, and larger than in the male; the legs are shorter, and the feet smaller. The shoulders are round, but the width across them, compared with that of the hips, is not so great as in man; the arms are shorter, fatter, and more rounded; the same is the case with the fore-arm; the hand is smaller, and softer, and the fingers are more delicate.

The whole frame of the female is more slender; the bones are smaller, their tissue is less compact, and the prominences and corresponding depressions are less marked; the subcutaneous cellular tissue is more abundant, and filled with a whiter and firmer fat; a similar adipous tissue fills up the intervals between the muscles, so that the whole surface is rounder, and more equable, than that of the male; the skin is more delicate, whiter, better supplied with capillary vessels, and less covered with hair; the hair of the head, on the other hand, is longer, finer, and more flexible; the nails are softer and of a redder hue; the muscles of the countenance are less distinctly marked, so that the expression of the eye, and the emotions, which occasion elevation or depression of the angles of the mouth,—laughing and weeping, for example,—are more strongly

marked. On the whole, the general texture of the organs is looser and softer.

The above observations apply to what may be termed the *standard female*,—one whose natural formation has not been interfered with by employments, which are usually assigned to the other sex. It can be readily understood, that if the female has been accustomed to the laborious exercise of her muscles, they may become more and more prominent, the interstices between them more and more marked, the projections and depressions of the bones on which they move more distinct; the whole of the delicacy of structure may be lost; and the skeleton of the female, thus circumstanced, may be scarcely distinguishable from that of the inactive male, except in the proportions of the pelvis, in which the sexual differences are chiefly and characteristically situated.

Many of the functions of the female are no less distinctive than the structure. The senses, as a general rule, are more acute, whether from original delicacy of organization, or from habit, is not certain;—probably both agencies are concerned. The intellectual and moral faculties are also widely different, and this, doubtless, from original conformation; although education may satisfactorily account for many of the differences observable between the sexes. Gall is one of the few anatomists, who have attended to the comparative state of the cerebral system in the sexes; and the results of his investigations lead him to affirm, that there is a striking difference in the developement of different parts of the encephalon in the two, which he thinks may account for the difference observable in their mental and moral manifestations. In the male, the anterior and superior part of the encephalon is more developed; in the female, the posterior and inferior; the former of these he conceives to be the seat of the intellectual faculties; the latter of those feelings of love and affection, which seem to preponderate in the character of the female. We have elsewhere said, that the views of Gall, on this subject, are not yet received as confirmed truths, and that we must wait until farther experience and multitudinous observations shall have exhibited their accuracy, or want of foundation. Independently, however, of all considerations deduced from organization, observation shows, that the female exhibits intellectual and moral differences, which are by no means equivocal. The softer feelings predominate in her, whilst the intellectual faculties have the preponderance in man. The evidences and character of the various shades of feeling and susceptibility, and the influence of education and circumstances on these developements, are interesting topics for the consideration of the moral philosopher, but admit of little elucidation from the labours of the physiologist. The only inference, to which he can arrive, is, that the causes of the diversity are laid in organization, and become unfolded and distinctive by education. The precise organization he is unable to depict, and the influence of circumstances on the mind it is scarcely his province to consider.

The function of muscular motion is, owing to organization, more feebly executed. We have already remarked, that the bones are comparatively small, and the muscles more delicately formed. The energy of the nervous system is also less; so that all the elements for strong muscular contraction are by no means in the most favourable condition; and, accordingly, the power the female is capable of developing by muscular contraction is much less than that of the male. Her locomotion is somewhat peculiar,—the wide separation of the hip-joints, owing to the greater width of the pelvis, giving her a characteristic gait. The vocal organs exhibit differences, which account for the difference in the voice. The chest and the lungs are of smaller dimensions; the trachea is of less diameter; the larynx smaller; the glottis shorter and narrower; and the cavities, communicating with the nose, are of smaller size. This arrangement causes the female voice to be weaker, softer, and more acute. The muscles of the glottis, and the ligaments of the glottis themselves, are apparently more supple, so as to admit of the production of a greater number of tones, and to favour singing. The phenomena of expression, as we have often remarked, keep pace with the condition of the intellectual and moral faculties, and with the susceptibility of the nervous system. As this last is generally great in the female, the language of the passions, especially of the softer kind, are more marked in her.

The functions of nutrition present, also, some peculiarities. With regard to digestion, less food is generally required; the stomach is less ample; the liver smaller; and frequently,—at least more frequently than in the male,—the dentes sapientiæ do not appear. The desire for food at the stated periods is not so powerful; and it is generally for light and agreeable articles of diet rather than for the very nutritious; but the appetite returns more frequently, and is more fastidious, owing to the greater sensibility of the digestive apparatus. This, however, is greatly an affair of habit, and we have more instances of prolonged abstinence in the female than in the male. The circulation is generally more rapid, the pulse being less full, but quicker. Of the secretions, that of the fat alone requires mention, which is usually more abundant and the product firmer. The cutaneous transpiration is less active, and the humour has a more acidulous odour. The urine is said, by some writers, to be less abundant, and less charged with salts; whence, it is asserted, there is less disposition to calculous affections. So far, however, as we have had an opportunity for judging, it is secreted in greater quantity, and this may partly account for its seeming to have a smaller quantity of salts in any given amount; but the truth is, the freedom of the female from calculous affections is greatly owing to the shortness and size of the urethra, which admits the calculus to be discharged with comparative facility; and it is a common observation, that where the males of a family, hereditarily predisposed to gout, become, owing to their greater exposure to the exciting causes, affected with that

disease, the females may be subject to calculous disorders,—the two affections appearing to be, in some respects, congenerous. For the reasons already mentioned, stone rarely forms in the bladder of the female, and the operation of lithotomy is scarcely ever necessary. The desire to evacuate the contents of the bladder occurs more frequently in the female, probably, in part, owing to habit; and, in part, to the greater mobility of the nervous system.

In addition to these differences, as regards the secretions, the female has one peculiar to herself,—menstruation,—which has already engaged attention. In the progress of life, too, the glandular system undergoes evolutions which render it especially liable to disease. About the period of the cessation of the menses,—sooner or later,—the mammæ frequently take upon themselves a diseased action, and become scirrhous and cancerous so as to require the organs to be extirpated.

In the treatment of disease, these sexual peculiarities have to be borne in mind. Owing to the greater mobility of the nervous system in the female, she usually requires a much smaller dose of any active medicine than the male; and, during the period when the sexual functions are particularly modified, as during menstruation, gestation, and the child-bed state, she becomes liable to various affections, some of which have been referred to elsewhere; others belong more appropriately to works on pathology, therapeutics or obstetrics.

The *acquired* differences, which we observe amongst individuals, are extremely numerous. The effect of climate on the physical and mental characteristics is strikingly exhibited. The temperate zone appears to be best adapted for the full developement of man, and it is there, that the greatest ornaments of mankind have flourished, and that science and art have bloomed in exuberance; whilst in the hot, enervating regions of the torrid zone, the physical and moral energy are prostrated; and the European or Anglo-American, who has entered them full of life and spirits, has left them after a few years residence, listless and shorn of his proudest characteristics. Nor is the hyperborean region more favourable to mental and corporeal developement; the sensibility being obviously blunted by the rigours of the climate. The effect of locality is, perhaps, most signally exemplified in the *Crétin*, and the *Goîtreux*, of the Valais, and of the countries at the base of lofty mountains in every part of the globe; as well as in the inhabitants of our low countries, who are constantly exposed to malarious exhalations, and bear the sallow imprint on the countenance.

Not less effective in modifying the character of individuals is the influence of the way of life, education, profession, government, &c. The difference between the cultivated and the uncultivated; between the humble mechanic, who works at the anvil or the lathe, and him

whose avocation, like that of the lawyer and the physician, consists in a perpetual exercise of the organ of intellect; and between the debased subject of a tyrannical government, and the independent citizen of a free state,—

"Lord of the lion heart and eagle eye,"

is signal and impressive.

To these acquired differences in individuals from extraneous or intrinsic causes we must refer *habit*, which has been defined,—an acquired disposition in the living body, become permanent, and as imperious as any of the primitive dispositions. It is a peculiar state or disposition of the mind, induced by the frequent repetition of the same act.

Custom and habit are frequently used synonymously; but they are distinct. Custom is the frequent repetition of the same act; habit is the effect of such repetition. By custom we dine at the same hour every day; the artificial appetite induced is the effect of habit.

The functions of the frame are variously modified by this disposition, being, at times, greatly developed in energy and rapidity, at others, largely diminished. If a function be over and over again exerted to the utmost extent of which it is capable, both as regards energy and activity, it becomes more and more easy of execution; the organ is daily better adapted for its production, and is so habituated to it, that it becomes a real want,—a *second nature*. It is in this way, that we accustom the organs of speech, locomotion, &c. to the exercise of their functions, until, ultimately, the most varied combinations of the muscular movements of the tongue and limbs can be executed with surprising facility.

If, on the contrary, the organs of any function possess unusual aptitude for accomplishing it, and we accustom ourselves to a minor degree of the same, we ultimately lose a part of the aptitude, and the organs become less inclined, and less adapted, to produce it. By custom we may habituate ourselves to receive an unusually small quantity of nutriment into the stomach, so that at length it may become impracticable to digest more.

A similar effect occurs as regards the quantity of the special irritant, which we allow to impinge on any of the organs of sense. If we accustom them to be feebly impressed, yet sufficiently so for the performance of their functions, they become incapable of supporting a greater quantity of the special irritant without indicating suffering. The miner can see into the farthest depths of his excavations, when, to the eye of one, who has descended from the bright light of day, all seems enveloped in obscurity. In this case, the sensibility of the organ of sight is developed to such an extent, that if the individual be brought into even a feeble light, the impression is extremely painful. The nyctalope is precisely so situated. His nerves of sight

are so irritable, that, although he can see well in the night, he is incapable of accurate discrimination by day. On the other hand, exposure to intense light renders the sensibility of the visual nerves so obtuse, that objects are not so readily perceived in obscurity. The hemeralope, who sees in the day and not in the night, and who is consequently the anthiteton of the nyctalope, has the nervous system of vision unusually dull, and incapable of excitement by feeble impressions.

It may be laid down, as a general principle, that if we gradually augment the stimulus applied to any organ of sense, it becomes less susceptible of appreciating minor degrees of the same irritant; so that, in this way, an augmented dose of the irritant is progressively required to produce the same effect. This is daily exemplified by the use of tobacco,—either in the form of chewing, smoking, or snuffing,—which becomes a confirmed habit, and can only be abandoned—without doing great violence to the feelings—by attention to the principle deduced from practice,—that by gradually following the opposite course to the one adopted in acquiring the habit—that is, by accustoming the nerve of sense to a progressive diminution in the dose of the stimulus—an opposite habit may be formed, and the evil, in this manner, be removed.

When, by habit, we acquire extreme facility in executing any function, it may be accomplished apparently without the direct interference of volition. This is peculiarly applicable to the voluntary motions. We have elsewhere shown, that, in this case, habit only communicates the facility, and that there is no natural sequence of motions, and, consequently, no reason,—as in executing a rapid musical movement,—why one movement of the fingers should follow rather than another, unless volition were the guiding power. Volition, as Dr. Parr has remarked, is not an exertion of mind, but apparently a simple impulse directed almost necessarily to an end; and it is affected by custom, nearly like the organs of the body. Thus, a sensation, which excited a perceptible exertion of volition, will, in time, produce it and the correspondent action, without our being sensible of its interference; and so rapid is this progress, that we seem to will two ends or objects at the same time, though they are evidently, when examined, distinct operations. But though, by custom, we are no longer sensible of bodily impressions, or of the exercise of volition, the corporeal organs, in their several functions, acquire, like those of the mind, peculiar accuracy of discrimination. The musician is not, for instance, sensible of his willing any one motion; yet with the most exquisite nicety he touches a particular part of the string of the violin, and executes a variety of the nicest and most complicated movements with the most delicate precision.

It is a common remark, that "habit blunts the feeling but improves the judgment." To a certain extent this is true; but the feeling is not blunted unless the stimulant, which acts upon the organ of sense, is too powerful, and too frequently repeated. When mode-

rately exercised, the effect of education, in perfecting all the senses, is strongly exhibited. Sensations, often repeated, cease to be noticed, not because they are not felt, but because they are not heeded; but if the attention be directed to the sensation, custom adds to the power of discrimination. Hence the sailor is able to detect the first appearance of a sail in the distant horizon, when it cannot be perceived by the landsman; and a similar kind of discrimination is attained by the due exercise of the other senses. This greater power of discrimination is doubtless owing to improvement in the cerebral or percipient part of the visual apparatus; but we have no evidence, that the organ of vision has its action necessarily blunted.

It has been presumed, by some physiologists and metaphysicians, that the will, by custom and exercise, may acquire a power over certain functions of the body, which were not originally subject to it; nay, some speculatists have gone farther, and affirmed, that all the involuntary functions were originally voluntary, and that they have become involuntary by habit. Stahl and the other animists, who regarded the soul as the formative and organizing agent in animals, asserted, that it excites the constant movements of the heart, and of the respiratory, digestive and other nutritive organs, by habits so protracted and inveterate, and so naturalized within us, that these functions can be effected without the aid of the will, and without the slightest attention being paid to them. Respiration, according to them, is originally voluntary; but, by habit, will becomes spontaneity; so that there is no farther occasion to invoke volition. Respiration goes on night and day, when we are asleep as well as awake; and they regard, as a proof that the action was originally dependent upon free will, that we are still able to accelerate or retard it at pleasure. They cite, moreover, the case of Colonel Townshend, related in another part of this work, to show, that the action of the heart is capable of being influenced by the will; and the fact that it is accelerated or retarded under the different passions.

Condillac, Lamarck,* and Dutrochet, again, fantastically assert,

* The views of this distinguished naturalist, regarding the effect of habit on organization, which he considers to tend to greater and greater complication, are most singular and fantastic. It is not, he considers, the organs of an animal that have given rise to its habits; on the contrary, its habits, mode of life, and those of its ancestors have, in the course of time, determined the shape of its body, the number and condition of its organs, and the faculties, which it enjoys. Thus, the otter, the beaver, the waterfowl, the turtle, and the frog were not made web-footed that they might swim; but their wants having attracted them to the water, in search of prey, they stretched out their toes to strike the water, and move rapidly along its surface. By the repeated stretching of their toes, the skin, which united them at the base, acquired a habit of extension, until, in the course of time, they became completely web-footed. The camelopard, again, was not gifted with a long flexible neck, because it was destined to live in the interior of Africa, where the soil was arid, and devoid of herbage; but, being reduced, by the nature of the country, to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its forelegs became longer than the hinder, and its neck so elongated that it could raise its head to the height of twenty feet above the ground!—"*Philosophie Zoologique*," Tom. I. p. 218, and T. II. p. 451.—Edit. 1830.

that the different instincts, observed to prevail so powerfully in animals, are mere products of an acquired power transmitted through successive generations.

The objections to all these views are,—that the functions in question are as well performed during the first day of existence as at an after period, and are apparently as free from the exercise of all volition. The heart, indeed, beats through fœtal existence for months before the new being is ushered into the world; and when, if volition be exerted at all, it can only be so obscurely. The case of Colonel Townshend is strange—passing strange—but it is almost unique, and the power of suspending the heart's action was possessed by him a short time only prior to dissolution. All the functions in question must, indeed, be esteemed *natural*, and instinctive, inseparably allied to organization; and hence differing from the results of habit which is always *acquired*.

The opinion of Bichat, on the other hand, was, that habit influences only the animal functions, and has no bearing on the organic or nutritive. But this is liable to objections. We have seen, under *digestion*, that if a bird, essentially carnivorous in its nature, be restricted to vegetable food, the whole digestive economy is modified, and it becomes habituated to the new diet. We know, also, that where drains are established in any part of the body, they become, in time, so much a part of the physiological condition of the frame, that they can only be checked with safety by degrees.

In the administration of medicines, habit has always to be attended to. The continued use of a medicine generally diminishes its power—hence the second dose of a cathartic ought to be larger than the first, if administered within a few days. Certain cathartics are found, however, to be exceptions to this. The Cheltenham water, and the different saline cathartics, are so. The constitution, so far from becoming reconciled to lead by habit, is rendered more and more sensible to its irritation. Emetics, too, frequently act more powerfully by repetition. Dr. Cullen asserts, that he knew a person so accustomed to excite vomiting on himself, that the one-twentieth part of a grain of tartarized antimony was sufficient to produce a convulsive action of the parts concerned in vomiting. As a general rule, however, remedies lose their effect by habit, and this is particularly the case with tonics; but if another tonic be substituted for a day or two, and then the former be resumed, it will produce all its previous effects.

Association, employed abstractedly, is a principle of the animal economy nearly allied to habit. When two or more impressions of any kind have been made upon the nervous system, and repeated for a certain number of times, they become associated; and if one of them only be produced it will call up the idea of the others. It is a principle, which is largely invoked by the metaphysician, and by which he explains many interesting phenomena of the human mind, especially those connected with our ideas of beauty, or the

contrary; our likes and dislikes, and our sense of moral propriety. Darwin employed it to explain many complicated functions of the economy; and he laid it down as a law, that all animal motions, which have occurred at the same time or in immediate succession, become so associated, that when one of them is reproduced, the other has a tendency to accompany or succeed it. The principle has, doubtless, great agency in the production of many of the physical, as well as mental, phenomena; but its influence has been overrated; and many of the consecutive and simultaneous actions, to which we have referred under the head of *correlation of functions*, take place, apparently as well the first time they are exerted, as subsequently. Sucking and deglutition are good cases of the kind. Soon after birth, the muscles of the lips, cheeks, and tongue are contracted to embrace the nipple, and to diminish the pressure in the interior of the mouth; and, as soon as the milk has flowed to the necessary extent into the mouth, certain voluntary muscles are contracted. These propel the milk into the pharynx, where its farther progress is accomplished by muscles, *associated* or connected functionally, but not in the sense we are now employing the epithet; for here one action could not suggest another, according to the definition we have given of *association*, which requires that the acts should have been executed previously. Many of the cases, in fact, ascribed by Darwin and Hartley to the agency of this principle, are instinctive actions, in which a correlation—as in the case of deglutition—exists, but without our being able to explain the nature of such correlation, any more than we can explain other complicated actions and connexions of the nervous system, of which this is doubtless one. Some of the most obstinate diseases are kept up by habit, or by accustomed associated motions; and, frequently, the disease will seem to continue from this cause alone. Whenever intermittent fever, epilepsy, asthma, chorea, &c. have been long established, the difficulty of removing the influence of habit, or the tendency to recurrence, is extreme. In such cases, the principle of revulsion can be invoked with much advantage by the therapeutist.

Lastly, the principle of *imitation* falls appropriately under this section. It may be defined as—that consent of parts, depending on similar organization, which, under the influence of the brain, enables them to execute acts similar to those executed by the same parts in another individual. Imitation, consequently, requires the action of the brain; and differs from those actions that are natural or instinctive to organs. For example, speech requires the action of imitation; whilst the ordinary voice or cry is effected by the newborn, and by the idiot, who are incapable of all observation, and consequently of imitation. The mode, in which speech is acquired, offers us one of the best examples of this imitative principle,—if we may so term it. At a very early period, the child hears the sounds addressed to it, and soon attaches ideas to them. It dis-

covers, moreover, that it is capable of producing similar sounds with its own larynx, and that these sounds are understood, and are inservient to the gratification of its wants; and, in this way, speech, as we have elsewhere seen, is acquired. The difficulty is to understand in what manner this singular consent is produced. Sir Gilbert Blane has properly remarked, that the imitation of gestures is, at first sight, less unaccountable than that of sounds; as they are performed by members which are objects of sight, and would seem therefore to be more readily transferable to the corresponding parts of another person: but he probably errs, when, farther on, he remarks, that when children begin to articulate, they first attempt those letters, in the pronunciation of which the motions of the organs are the objects of sight; such as the *p* and *b*, among consonants, and the broad *a*, among the vowels, "giving occasion to a well-known etymology, from the infantile syllables, expressive of father and mother in all languages." We do not think, that this explanation is happy; and have elsewhere attempted to show, that the combination of letters, and the words referred to, are first enunciated, because they are the easiest of all combinations; and that the expressions of *mama*, *papa*, &c. are employed long before the child has acquired the power of imitation, and long prior to his attaching the meaning to the words which he is subsequently taught to adopt.

It is certainly singular how the child can learn to imitate sounds, where the action of the organs concerned is completely concealed from view. The only possible way of explaining it is to presume, that it makes repeated attempts with its vocal apparatus to produce the same sound which it hears: and that it recollects the sensation produced by the contraction of the muscles when it succeeds, so as to enable it to repeat the contraction of the muscles, and the sensation, at pleasure. This is, however, a case in which volition is actively exerted. We have others, where the action occurs in spite of the individual, as in yawning. We see the action in a second person, and, notwithstanding all our attempts to the contrary, the respiratory organs are excited through the brain, and we accomplish the same act. Nay, even thinking of the action will be sufficient to arouse it. Of a like nature to this, is the sympathetic contraction of the uterus, which comes on, where a pregnant female is in the lying-in chamber during the accouchement of another, and to which we have referred under the head of Sympathy.

Many morbid phenomena are excited in a similar manner;—of these, squinting and stammering are familiar examples.

Sect. IV. Of the Varieties of Mankind.

To determine the number of varieties, into which the great human family may be divided, is a subject, which has been considered to

belong so completely to the naturalist that we shall pass it over with a brief inquiry.

If we cast our eye over the globe, although we may find, that mankind agree in their general form and organization, there are many points in which they differ materially from each other. With those forms, proportions and colours, which we consider so beautiful in the fine figures of Greece,—to use the language of Mr. Lawrence,—contrast the woolly hair, the flat nose, the thick lips, the retreating forehead, advancing jaws, and black skin of the negro; or the broad, square face, narrow oblique eyes, beardless chin, coarse, straight hair, and olive colour of the Calmuck. Compare the ruddy and sanguine European with the jet black African, the red man of America, the yellow Mongolian, or the brown South-Sea Islander; the gigantic Patagonian, or the dwarfish Laplander; the highly civilized nations of Europe, so conspicuous in arts, science, literature, in all that can strenghten and adorn society, or exalt and dignify human nature, to a troop of naked, shivering, and starved New Hollanders, a horde of filthy Hottentots, or the whole of the more or less barbarous tribes, that cover nearly the entire continent of Africa; and although we must refer them all to the same species, they differ so remarkably from each other as to admit of being classed in a certain number of great varieties; but, with regard to the precise number, naturalists have differed materially.

Whatever changes have been impressed upon mankind can, of course, apply only to the descendants of Noah. The broad distinctions, we now meet with, could not have existed in his immediate family, saved with him at the time of the deluge. They must necessarily have all been of the same race. None of our investigations on this subject can, consequently, be carried back into antediluvian periods. Hence, the region, on which the ark rested, must be looked upon as the cradle of all mankind.

The question of the original residence of man has frequently engaged the attention of the philologist. It is one, which could be answered positively by the historian only, but unfortunately the evidence we possess of an historical character is scanty in the extreme, and the few remarks, in the sacred volume, insufficient to lead us to any definite conclusion. As far back as the date of the most remote of our historical records,—which extend to about two thousand years prior to the Christian era,—we find the whole of Asia and a part of Africa,—probably a large part,—peopled by different nations, of various manners, religion, and language; carrying on extensive wars with each other; with, here and there, civilized states, possessing important inventions of all kinds which must have required a length of time for discovery, improvement, and diffusion.

After the subsidence of the deluge, the waters would first recede from the tops of the highest mountains, which would thus be the earliest habitable; and, in such a situation, the family of Noah pro-

bably increased, and thence spread abroad on the gradual recession of the waters. The earliest habitable region was probably the elevated region of middle Asia,—the loftiest in the world,—not the summits, which would be unsuitable, in every respect, for human existence, but some of the lofty plains, such as that, of which the well-known desert Kobi or Schamo forms the highest point, and from whence Asia sinks gradually towards the four quarters, and the great mountain chains proceed that intersect Asia in every direction.

This has been suggested by Herder and Adelung as the cradle of the human race. In the declivities of this elevated region, and of its mountain chains, all the great rivers arise that flow on every side through this division of the globe. After the deluge, it would therefore soon become dry, and project, like an extensive island, above the flood. The cold and barren elevation of Kobi would not itself have been well adapted for the continued residence of our second parents, but immediately on its southern side lies the remarkable country of Tibet, separated by lofty ridges from the rest of the world, and containing within itself every variety of climate. Although on the snow-capt summits the severest cold perpetually prevails, summer eternally reigns in the valleys, and well-watered plains. The rice, too, the vine, pulse, and a variety of other productions of the vegetable kingdom, which man employs for his nutrition, are indigenous there; and those animals are found in a wild state, which man has domesticated and taken along with him over the earth;—the ox, horse, ass, sheep, goat, camel, swine, dog, cat, and even the valuable reindeer,—his only friend and companion in the icy deserts of polar countries. Zimmermann, indeed, asserts, that every one of the domesticated animals is originally from Asia. Close to Tibet, and immediately on the declivity of this great central elevation, is the charming region of Kaschemire, the lofty site of which tempers the southern heat into a protracted spring.

The probabilities in favour of the cradle of mankind having been situated to the south of the elevated region of middle Asia are considered to be strengthened by the circumstance of the nations in the vicinity possessing a rude, meagre and imperfect language, such as might be imagined to have existed in the infancy of the human intellect and of the world. Not less than two hundred millions of people are found there, whose language appears to be nearly as simple as it must have been soon after its formation. Kaschemire, by reason of the incessant changes, which it has experienced in ancient and modern times, has, indeed, kept pace with the rest of the world in the improvement of its language, but not so, apparently, with Tibet—its neighbour—and with China, and the kingdoms of Ava, Pegu, Siam, Tunkin, and Cotschinschina. All these extensive countries and these alone in the known world, according to Adelung, betray the imperfection of a newly-formed or primitive language. As the earliest attempt of the child is a stammering of monosyllabic notes, so, says that eminent philologist, must have been that of the original

child of nature; and, accordingly, the Tibetans, the Chinese, and their two neighbours to the south continue to stammer monosyllabically, as they must have been taught, thousands of years ago, in the infancy of their race. "No separation of ideas into certain classes, whence arose the parts of speech in cultivated languages. The same sound, which denotes *joyful*, signifies *joy* and to *gladden*, and this in every person, number and tense. No art, connexion, or subordinate ideas are united to the rude, monosyllabic root, thereby communicating richness, clearness and euphony to their meagre tongue. The rude, monosyllabic, radical ideas are placed, perhaps broken, and detached from each other, the hearer being left to supply the intermediate ideas. As the monosyllable admits of no inflection, the speaker either makes no distinction between cases and numbers, or he seeks for aid, in cases of great necessity, in circumlocution. The plural he forms, like the child, either by repetition,—*tree, tree*,—or by the addition of the words *much* or *more*, as *tree much, tree more. I much* or *I more* is the same to him as *we*."

From these and other circumstances, Adelung infers, that these monosyllabic languages are primitive and the honourable ancestors of all others;* that the immediate descendants of Noah originally occupied the favoured region which has been described, and, as population increased, spread into the neighbouring districts, selecting, by preference, the near and charming regions of the south, east, and west. Hence we find, in the countries immediately bordering on Tibet, the earliest formed states, and the oldest civilization. History refers us to the east, for the primordial germs of most of our ideas, arts and sciences, whence they subsequently spread to the countries farther to the west,—to Media, Persia, and western Asia. It is probable that from this part of Asia, the sons of Noah,—Shem, Ham, and Japheth,—branched off in various directions, so as to constitute the three distinct stocks which are found to have divided the old world from time immemorial. These three are 1, the *White, Caucasian, Arabico-European*, or *European;* 2, the *Olive, Mongolian, Chinese, Kalmuck*, or *Asiatic;* and 3, the *Negro, Ethiopian, African, Hottentot*, &c. each of which has its own principal habitat;—the white being found chiefly in Europe and Asia Minor, Arabia, Persia, and India, as far as the Ganges, and in North Africa; the Mongol occupying the rest of Asia, and having its focus on the plateaux of Great Tartary and Tibet; and the negro race covering almost the whole of Africa, and some of the isles of New Guinea, the country of the Papous, &c. The white or Caucasian variety are supposed to be the descendants of Japheth, ("*audax Japeti genus*," Horace;)

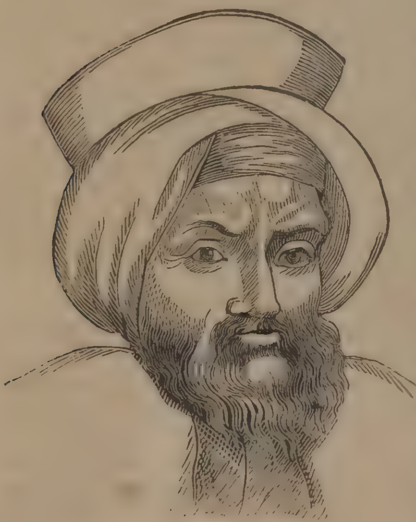
* This argument of Adelung is, however, more plausible perhaps than sound. It has been correctly remarked by the distinguished Duponceau, that, in all languages, there is a strong tendency to preserve their original structure, and that from the most remote period, to which the memory of man can reach, a monosyllabic language has never been known to become polysyllabic, or *vice versa*.

the Asiatic of Shem; whilst Ham is regarded as the parent of the unhappy African.

These three races,—the *Caucasian*, *Negro* ,and *Mongolian*,—are alone admitted by Cuvier, whose classification will serve our purpose as well as any of the others to which reference will be made presently.

1. The *Caucasian race* is chiefly distinguished by the elegant form of the head, which approximates to a perfect oval. It is also remarkable for variations in the shade of the complexion and colour of the hair. From this variety, the most civilized nations have sprung. The name *Caucasian* was given to it from the groupe of mountains, between the Caspian and the Black Sea,—tradition seeming to refer the origin of this race to that part of Asia. Even at the present day, the peculiar characteristics of the race are found in the highest perfection amongst the people who dwell in the vicinity of Mount Caucasus,—the Georgians and Circassians,—who are esteemed the handsomest natives of the earth.

Fig. 194.



Caucasian variety.

The marginal figure is given by Blumenbach as a specimen of the Caucasian race, near the original residence whence the epithet is derived. It represents Jusuf Aguiah Efendi, formerly ambassador from the Porte to London.

The Caucasian race has been subdivided into several great nations or families:—1. The *Arabs*, comprising the Arabs of the desert or the Bedouins, the Hebrews, the Druses and other inhabitants of Libanus, the Syrians, Chaldæans, Egyptians, Phœnicians, Abyssinians, Moors, &c. 2. The *Hindoos* on the European side of the Ganges;—as the inhabitants of Bengal, of the coasts of Coromandel and Malabar, the ancient Persians, &c. 3. The *Scythians* and *European Tartars*, comprising also the Circassians, Georgians, &c. 4. The *Kelts*, a dark-haired race, the precise origin of which is unknown, but presumed to be Indian. The descendants of this race are the Gauls, Welsh, Rhætians, &c. &c.; and, lastly, the *Goths*, a fair-haired race, the ancestors of the Germans, Dutch, Swedes, Danes, &c.

That the time of the first peopling of the European countries

must have been very remote is exhibited by the fact, that at the dawn of history, the whole of Europe, from the Don to the mouth of the Tagus, was filled with nations of various physical characters and languages, and bearing striking marks of intermixture and modification. At this period, there were, in Europe, at least six great nations. 1st. The *Iberians* with the *Cantabri*, in Spain, in a part of Gaul, and on the coasts of the Mediterranean as far as Italy. 2dly. The *Kelts*, in Gaul, in the British Isles, between the Danube and the Alps, and in a part of Italy. 3dly. The *Germani* or *Goths*, between the Rhine, the Danube and the Vistula. 4thly. The *Thracians* with the *Illyrians*, in the south-east of Europe, and in western Asia. 5thly. The *Sclavi*, in the north: and 6thly. The *Fins* in the north-east. It is not improbable, that these different races migrated from Asia in the order we have mentioned:—such is the theory of certain historians and philologers, and there is some reason for adopting it. They, who migrated first, would probably extend their wanderings until they were arrested by some invincible obstacle, or until the arrival of fresh tribes would drive them onwards farther and farther towards the west. In this way, they would ultimately reach the ocean, which would effectually arrest their farther progress, unless towards the south and the north. The descendants of the ancient Iberians do now actually occupy the west of Spain,—the residence probably of their forefathers.

Nearly about the same time, perhaps, as the Iberians undertook their migration, the Kelts, a populous tribe, migrated from some part of Asia, and occupied a considerable portion of middle Europe. To these succeeded the Goths, to the north, and the Thracians to the south; whilst the Sclavi, the last of the Asiatic emigrants, wandered still farther north. It is not easy to determine the precise link, occupied by the Fins in this vast chain of nations. They were first known to history as a peculiar people in the north of Europe, but whence they proceeded, or whether they occupied their position to the north of the Germani from choice, or were urged onwards by their more powerful neighbours, we know not.

So long as there was sufficient space for the nations to occupy, without disturbing the possessions of their neighbours, they probably kept themselves distinct; but as soon as the land was filled, a contest arose for the possession of more extensive or more eligible regions; wars were, consequently, undertaken, and the weaker gradually yielded their possessions, or their sovereignty, to the stronger. Hence, at the very dawn of history, numerous nations were met with, amalgamated both in blood and language;—for example, the Kelto-Iberians of Spain; the Belgæ or Kymbri of Gaul and Britain; the Latins, and other nations of Italy, and probably many, whose manners, characters, and language had become so melted into each other as to leave little or no trace of the original constituents. The Letti, Wallachians, Hungarians, and Albanians of eastern Europe, are supposed to afford examples of such amalgamation, whilst the

mighty Sclavonic nation has swallowed up numbers of less powerful tribes, and annihilated even their names for ever. This it is, which frequently embarrasses the philological historian; and prevents him, without other evidence, from deducing with accuracy the parent stocks or the most important components in ethnical admixtures.

2. The *Negro*, *African*, *Ethiopian* or *Black man* of Gmelin, occupies a less extensive surface of the globe, embracing the country of Africa which extends from the southern side of Mount Atlas to the Cape of Good Hope. This race is evidently of a less perfect organization than the last, and has some characteristics, which approximate it more to the monkey kind. The forehead is flattened and retiring; the skull is smaller, and holds from four to nine ounces of water less than that of the European. On the other hand, the face, which contains the organs of sense, is more developed, and projects more like a snout. The lips are large; the cheek bones prominent; the temporal fossæ hollower; the muscles of mastication stronger; and the facial angle is smaller;—the head of the negro, in this respect, holding a middle place between the Caucasian and the ourang-outang. The nose is expanded; the hair short and woolly, very black and frizzled. Skin black. This colour is not, however, characteristic of the race, as the Hottentots and Caffres are yellow.

Fig. 195.

Negro variety.

The marginal figure is the head of J. J. E. Capitein, selected by Blumenbach as the representative of his race. He was an intelligent negro, and published several sermons and other works in Latin and Dutch. His portrait was taken by Van Dyk. This case of great intelligence in the negro is not unique; and it exhibits what may be expected from him under favourable circumstances. In almost all situations in which he is found, it is the state of slavery, and degradation, and no inference can be deduced regarding his original g r u n d k r a f t —as the Germans call it—or intellectual capability. Hayti has afforded numerous examples of the sound judgment, and even distinguished ability, with which her sable inhabitants are capable of conducting, not only the municipal, but the foriegn concerns of a considerable community. It must be admitted, however, that from organization, this race would seem to be, *cæteris paribus*, less fitted for intellectual distinction than the Caucasian,

3. The *Mongolian* or *Asiatic*, *Kalmuck* or *Chinese* race, the *brown man* of Gmelin, is recognized by prominent and wide cheek bones;

flat, square visage; small and oblique eyes; straight and black hair; scanty beard, and olive complexion.

The marginal head is from Blumenbach. It is that of Feodor Ivanowitsch, a Kalmuck, given by the empress of Russia to the hereditary princess of Baden. He was educated at Carlsruhe, and was a most distinguished painter at Rome. The portrait was sketched by Feodor himself.

Fig. 196.

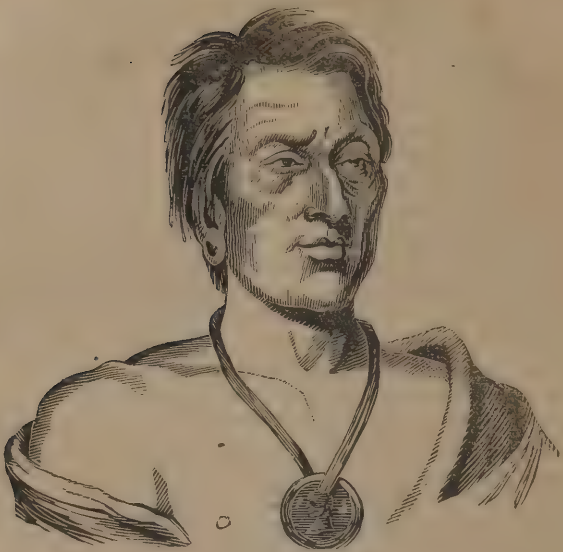
Mongolian variety.

The Mongols are spread over the central and eastern parts of Asia, with the exception of the peninsula of Malacca. They likewise stretch along the whole of the Arctic regions, from Russia and Lapland to Greenland, and the northern parts of the American continent, as far as Behring's Straits,—the Laplanders and Esquimaux being evidently of the same race as the Koriaks, Kamtschadales, Japanese, &c. of the Asiatic continent.

Such are the three varieties whence, in the opinion of Cuvier, all the rest may be deduced. Rudolphi and others have added to these the race, which is peculiar to our own country, and has by some been esteemed indigenous.

The *American race* or *red man* of Gmelin differs greatly in stature, colour, and physiognomy in various parts of the continent, but his medium height corresponds with that of the European. His colour is from a cinnamon-brown to a deep copper. The hair is almost always black, straight and stiff. The features are large and strongly marked, except the eyes, which are commonly deep-seated, or sunk in large sockets. The forehead is generally low, somewhat compressed at the sides, and slightly retreating. Facial angle about 80°. Nose generally considerably raised from the face, sometimes arched; cheek bones high, and widely separated; angle of the jaw broad, and chin square. The accompanying head is that of Ongpatonga, (*Big Elk*,) chief of the Omawhaw Indians, and is taken from the *American Natural History* of the lamented Godman.

Fig. 197.



American variety.

Other naturalists, as Blumenbach, Dumeril, Lawrence, &c.—add to these four varieties a fifth,—the *Malay* or *Australian;* the *Tawny man* of Gmelin, owing to the difficulty of referring it either to the Caucasian Indian, or to the Chinese Mongolian, situated in its vicinity. This Malay variety extends from Malacca to the most remote islands of the great Indian and Pacific ocean, from Madagascar to the Maldives, inclusive; inhabits Sumatra, Java, Borneo, Celebes, and the adjacent islands; the Molucca, Ladrone, Philippine, Marian, and Caroline groupes; New Holland, Van Dieman's Land, New Guinea, New Zealand, and the various islands scattered through the South Sea. It is termed *Malay*, because supposed to have proceeded originally from the Peninsula of Malacca, and to have spread thence over the adjacent islands, a supposition, which is not confirmed by history: on the contrary, according to Mr. Marsden, it is clearly demonstrated, that the Malays went from Sumatra to Malacca in the twelfth century. No well-marked, common characters can be assigned to this variety; for, under the term *Malay*, races are included, which seem to differ materially from each other; so much so, indeed, as to induce many naturalists to refuse the admission of the Malay as a distinct variety. Their colour may be said to be brown, in various shades, from a light tawny, to almost a black; the forehead is low and round; the nose full and broad; nostrils wide; mouth large; hair thick, crisp, and always black, as well as the iris, Fig. 135 exhibits an individual of this race: it is the head of a New

Zealand chief. Cuvier, Rudolphi, Virey and others consider the Malay variety to be a mixture of the Mongol of Asia and the negro of Africa.

In New Guinea, and the small islands around, the *Papous* are found, who resemble the negroes yet more strongly; and similar races are met with in the Archipelago of the Holy Ghost, and in the isles of Andaman and Formosa. They are presumed to belong really to the negro race, and to have descended perhaps from individuals of that variety, who had wandered, or been driven, from their original settlements. Some of them resemble the Guinea negro in every particular.

Of late years, many other races have been added to those admitted by Blumenbach; especially by Messrs. Virey, Desmoulins, Malte-brun, and Bory de Saint-Vincent.

The various classifications, indeed, exhibit the vacillation, which yet exists regarding the precise number of races that should be admitted. Every division must necessarily be arbitrary, and the individuals composing each variety are far from being alike. We find the greatest diversity, for example, amongst the nations of the Caucasian variety, and even amongst any of its subdivisions. The French can be distinguished from the German, the Spaniard from the English, &c. and if we were to push the system of subdividing, which appears at present to be fashionable, we might constitute almost every nation of the globe into a distinct variety.

It has been an oft agitated question, whether all the varieties amongst mankind must be regarded as belonging to the same species,—the differences, which we observe, having been accomplished by extraneous circumstances acting through a long succession of ages; or whether they must not be regarded as distinct species, *ab origine*. By many, the discussion of this subject has been esteemed not only unnecessary but profane, inasmuch as the sacred historian has unequivocally declared, that all mankind had a common origin. We have already remarked, however, that this is not a question, which concerns our first parents, but belongs exclusively to the family of Noah; for, in his descendants, all these varieties must necessarily have occurred. From the part of Asia, previously described, his immediate descendants probably spread abroad to the north and to the south, to the east and to the west; Europe being peopled by the migratory hordes, which proceeded towards the north-west, and Africa by those from south-western Asia. These migrations probably all took place by land, except in the case of our own continent, where a slight sea-voyage, of not more than thirty-nine miles, across Behring's Straits, even in frail vessels, would be sufficient to transport the emigrants without much risk of misadventure; and even this short voyage would be rendered unnecessary during the winter season, the Strait being solidified into a continuous mass of ice.

Europe probably received its inhabitants long before navigation occurred to any extent. Subsequently, when a coasting trade was

first established,—to which the enterprise of nations would necessarily be limited in the first instance, until by improved vessels and a better system of management they were enabled to brave the terrors of the ocean, and undertake their adventurous voyages of discovery, —many of the coasts, especially of the Mediterranean, received swarms of emigrants, a circumstance, which accounts for the motley population, observable, at an early period, in these regions. Carthage, we know, was settled by the Phœnicians, and Southern Italy and Spain, in this manner, received their Greek colonies. Dr. Copland has even expressed his belief in the view, that this continent was visited "by Phœnician navigators, the greater part of whom settled in it, particularly in Mexico; and that the imperfect navigation of that era prevented many of the adventurers, if not all of them, from returning." The notion is, however, altogether hypothetical.

The greatest difficulty has been,—to comprehend how the Caucasian and Ethiopian varieties could have originated from the same source. The other varieties of mankind, if we exclude the negro, could be referred, without much hesitancy, to the same primitive stock,—the changes being caused by adventitious circumstances operating for an immense period,—but it has seemed to many naturalists impossible to suppose, that the characters of the negro could, by any process, become converted into those of the European, or conversely.

The people of antediluvian times probably possessed but few physical differences, constituting one large family, modified, perhaps, to a certain extent, by circumstances, but not materially; the two antithetical races,—the white and the black,—first arising in postdiluvian periods. If we adopt this view, the question, regarding the difference of *species* between the white and the black, will require no agitation. But how are we to explain the essential differences, as to form and colour, which we notice amongst the nations of the earth?

In the infancy of anthropology, it was asserted, that the white races inhabit the cold and temperate regions of the earth, whilst the tawny and the darker races are situated under a more vertical sun. Within certain limits, the sun is certainly possessed of the power of modifying the colour. The difference between one, who has been for some time exposed to the rays of a tropical sun, and his brethren of the more temperate climates, is a matter of universal observation. The inhabitant of Spain is, in this way, distinguishable from the French, German, English, &c.; and hence we can understand, why the Southern Asiatic and African women of the Arab race, when confined within the walls of the seraglio, may be as white as the fairest Europeans. There are many exceptions, however, to the notion which has prevailed, that there is an exact ratio between the heat of the climate and the blackness of the skin. For example, at the extreme north of Europe, Asia, and America, we find the Laplanders, Samoiedes, Esquimaux, &c. with the skin very brown, and the hair and iris black; whilst, in the vicinity of the Laplanders, are

the Fins,—people of large stature compared with the Laplanders, with fair skins and bluish-gray eyes. In the same manner, to the south of the Greenlander,—of short stature, brown skin, and dark hair,—is the tall and fair Icelander. The Kelt of Wales, and of the western coast of Ireland, of the north of Scotland, and of the west of Bretagne, is still distinguished, by his dark hair and eyes, from the light-haired descendants of the Goth,—the German and the Scandinavian. Many distinct tribes exist in the interior of Africa, having a red or copper hue, with lank black hair, and in the midst of the black varieties of their species. A similar fact was observed by Humboldt in different parts of South America.

Again, the negro race is not always found in the torrid zone. On our own continent, none have ever been met with, except what have been imported; and these, after repeated descents, have still retained their original character; whilst, as we have seen, negroes are met with in Australia under a climate as cold as that of Washington. The fact of the slight mutation, effected by ages on the character of a race, is strikingly shown by the circumstance to which we have before referred,—that in some of the monuments of Egypt, visited by Belzoni and Champollion, representations of the negro, presumed to be upwards of three thousand years old, exhibit the features to be almost identical with those of the negro of the present day. The Jew affords an example of the same immutability, as well as the Esquimaux, who strikingly retain the evidences of their Kalmuck origin. Complexion, and, to a certain extent, the figure are doubtless modified by climate, but the essential characters of the organization remain little if at all changed.

Volney has fancifully supposed, that the elongated visage of the negro is owing to the wry face habitually made under exposure to the rays of the sun. Independently, however, of the objection, that this would be wholly insufficient to account for the striking peculiarities of the negro head, it has already been remarked, that these peculiarities do not exist among other races, inhabiting equally hot climes; and that the negro himself is not confined to those climates, and ought, consequently, to lose the *museau* or snout, when the country is so cool as to render the wry face or *moue* unnecessary.

It may then, we think, be concluded, that the evidence, in favour of the colour of the negro, of the red man, or of the tawny, being produced directly or indirectly by the solar rays, is insufficient to establish the point. One important argument in the negative is the fact, that in all cases, the children are born fair, and would continue so, if not exposed to the degree of solar heat, which had produced the change in their progenitors.

In addition to the influence of temperature and climate, that of food, and of different manners and customs has been frequently invoked, but without any precise results being deduced. The effect of difference in manners and customs is shown in the result of domestication on animals,—as in the case of the wild and the disci-

plined horse; of the bison and the ox; which last is regarded as the bison in a state of tameness. The precise causes of such modification we know not. It is not confined to the animal, but is signally evidenced in the vegetable. The flower of the forest, when received into the *parterre* and carefully nurtured, will develope itself in such a manner as to be with difficulty recognizable. The change seems to be produced by variation in climate and nutrition, but in what precise manner we know not.

The powerful modifying influence of locality on the developement of the moral and physical powers has been more than once referred to. Perhaps the most remarkable examples are met with at the base of lofty mountains, particularly of the Alps, and in some of the unhealthy districts of France especially. One of these is *cretinism*, a singular case of malformation, with which we are happily unacquainted in the United States.

This is a state of idiocy, which is remarkable in its subjects being always more or less deformed, and in its appearing to originate from local influences. The *crétin* has every characteristic of the idiot; and, in addition, is often distinguished by a large *gôitre* or swelling of the thyroid gland; by soft, flabby flesh; and by shrivelled, yellowish, or pale and cadaverous skin, covered, at times with filthy cutaneous eruptions. The tongue is thick and pendent; the eyelids large and projecting; the eyes gummy, red and prominent; the nose flat; the mouth gaping and drivelling; the face puffy, and, at times, violet-coloured, and the lower jaw elongated. In several, the forehead is broad inferiorly, and flattened and retreating above, giving the cranium the shape of a cone rounded towards its smaller extremity. The stature of the cretin is generally small, scarcely ever exceeding four feet and a few inches; the limbs are frequently malformed, and almost always kept in a state of flexion. All the cretins are not affected with goître. Some have large and short, whilst others have thin, and long, necks. Like the idiot, the cretin does not generally live long, scarcely ever surviving the thirtieth year.

Authors have differed in opinion on the causes of this deplorable condition. It is observed almost exclusively in the deep and narrow valleys at the foot of lofty mountains, and in mountain gorges. Hence it is common in that part of the Alps called the Valais or Wallais; in the valley of Aost, La Maurienne, &c. It is met with, too, at the foot of the mountains of Auvergne, the Pyrenees, the Tyrol, &c. De Saussure, Esquirol, Fodéré, Rambuteau,—and all who have had an opportunity of observing these miserable wrecks of humanity,—believe, that the great cause is the concentrated, moist, and warm air, which prevails, throughout almost the whole of the year, in the valleys and mountain gorges where it is found to exist.

After, all, perhaps, the strongest arguments,—in favour of extraneous circumstances occasioning, in the lapse of ages, the different varieties, which we observe in the great human family,—are those derived from the changes that must have occurred amongst many

of the inferior animals. The dog, in its wild state, has always pretty nearly the same characters; being covered with hair of the same colour; the ears and tail, and limbs, having the same shape; and it exhibits, apparently, the same powers and instincts; but, on this matter, our knowledge, derived from observation, is necessarily limited. Yet what a number of varieties are observed in this animal when it becomes domesticated; and how different from each other, in shape, colour, character of skin and instincts, are the spaniel, hound, grayhound, pointer, mastiff, terrier, cur, pug, lapdog, &c.; differences certainly as great as between the varieties of mankind. These differences, it is presumable, may have been produced partly by the occurrence of accidental varieties, affecting perhaps a whole litter,—male and female; so that if these, again, were to be coupled, the variety, thus accidentally caused, may have become permanent. Such accidental varieties occasionally occur in the human species, but they are soon lost, in consequence of the wise law that prevents individuals, within certain degrees of consanguinity, from marrying. It is by no means uncommon, for example, for different children of the same family, from some accidental cause, to be born with six fingers. The author has met with two families in each of which more than one individual was thus circumstanced; and Sir Anthony Carlisle has detailed the remarkable case of a family from this continent, where the superfluity extended, in the case of a female, to two thumbs on each hand, and to six toes on each foot. She married and had several children, who, in their turn, became parents, and transmitted the peculiarity to their children to the fourth generation. Now, if the members of this family had continued to marry in and in, a new race of individuals might have been perpetuated, possessing the unnecessary additions in question. Under existing laws and customs, it must always happen, that where such peculiarity exists in one parent only, it must soon become extinct; yet, as we have seen, it may be pertinacious enough to persist for some generations. Fortunately, also, it happens, that no change, which occurs accidentally in the parent after birth, is liable to be extended to the progeny. Were it otherwise, it will be at once seen, the most strange and innumerable varieties of races would exist. Where a limb had become distorted or amputated, a stock of one-limbed animals would be formed; the docked horse would propagate a mutilated colt; the operation of circumcision, performed on one parent, ought to be sufficient for the whole of his descendants, &c. &c.

In addition to this mode of accounting for the great number of varieties in animals of the same species, the influence of a difference in manners and customs, which we have already considered, has been invoked; and it has been conceived, that the effect of civilization and refinement on the human race may be analogous to that of domestication on the inferior animals. This kind of influence is said to be particularly observable amongst the inhabitants of Hindusthan, where, in consequence of the division into castes, the same condition of life, and the same occupation are continued without

change through many successive generations. The artisans, who are a superior class, are of a manifestly lighter complexion than the tillers of the soil; and, in many of the islands of Polynesia, the same difference exists between the classes as in Hindusthan.

The believers, then, in the Mosaic account of the creation, and the deluge, must regard all the varieties of mankind to have descended from the same family,—that of Noah,—and the different changes, which have been impressed upon their descendants, to be results of extraneous influences acting through a long succession of ages, added to the production perhaps of accidental varieties, which may have occurred in the very infancy of postdiluvian existence, when the intermarriage of near relations was unavoidable, and when such varieties would necessarily be perpetuated. The race of Ham appears to have been separated, if not wholly, at least in part, from their brethren by the malediction of Noah; and, whether we consider, that a physical alteration was comprised in the malediction, or that such alteration might occur accidentally, as in the cases of those with supernumerary toes and fingers, the very fact of intermarriage with the descendants of the other sons of Noah being prevented by the curse pronounced on Ham, (for many commentators read Ham for Canaan,) would necessarily lead to a perpetuation of the adventitious modification.

But, it has been asked, if all mankind have descended from one family, which of the varieties, now extant, must be regarded as their representative? On this we have nothing but conjecture to guide us. It has been supposed, by some, to be more probable, that the changes, induced upon mankind, have been in consequence of the progress from a state of barbarism to one of refinement, than the reverse; and hence, it has been conceived, that the variety ought to be considered primary, which, through all the vicissitudes of human affairs, has remained in the most degraded condition, and which in its structure, differs most materially from the variety that has uniformly enjoyed the greatest degree of civilization. Upon this principle, the Ethiopian would have to be regarded as the type of our first ancestors, and such is the opinion of Prichard, and of Bostock. Blumenbach, however, maintains the converse view. Bishop Heber, again, suggests, whether the hue of the Hindoo, which is a brownish-yellow, may not have been that of our first parents, whence the transition, he thinks, to the white and black varieties, might be more easy and comprehensible. Philology occasionally aids us in our historical deductions, but the evidence, afforded by it, has to be received with caution. The Hebrew names, like all original appellations, in perhaps all languages, are generally expressive, and therefore worthy of consideration in questions of this nature. The Hebrew word Adam, (אדם,) is not only the name of the first man, but it signifies man in the abstract, corresponding to the Greek, ανθρωπος, and the Latin, *Homo*. We are told, in the sacred volume, that, "in the day that God created man, in the like-

ness of God made he him; male and female created he them; and blessed them, and called their name Adam, in the day when they were created." The word Adam is derived from a Hebrew root, (אדם,) signifying "to be red," and, accordingly, it is not improbable, that his original hue was of that character.

The remarks already made, render it unnecessary to inquire into the mode, in which, according to the notions of Blumenbach, of Dr. S. S. Smith, or of Dr. Rush, the black colour of the Ethiopian has been produced. Blumenbach imagined, that the heat of the climate gives rise to an excessive secretion of bile; that in consequence of the connexion, which exists between the action of the liver and the skin, an acumulation of carbonaceous matter takes place in the cutaneous vessels, and that this process, being continued for a succession of ages, the black colour of the skin becomes habitual. Dr. Smith, of Princeton, had a similar opinion; he thought, that the complexion in any climate will be changed towards black, in proportion to the degree of heat in the atmosphere, and to the quantity of bile in the skin; and, lastly, Dr. Rush, in one of the strangest of the many strange views, which have emanated from that distinguished, but too enthusiastic, individual, has attempted to prove, "that the colour and figure of that part of our fellow creatures, who are known by the epithet of negroes, are derived from a modification of that disease which is known by the name of leprosy."

The following are his deductions from the "facts and principles" adduced in a communication, read before the *American Philosophical Society* in 1792, and printed in the fourth volume of the Transactions of that respectable body:—

"1. That all the claims of superiority of the whites over the blacks, on account of their colour, are founded alike in ignorance and inhumanity. If the colour of negroes be the effect of a disease, instead of inviting us to tyrannize over them, it should entitle them to a double portion of our humanity, for disease all over the world has always been the signal for immediate and universal compassion. 2. The facts and principles which have been delivered, should teach white people the necessity of keeping up that prejudice against such connexions with them, as would tend to infect posterity with any portion of their disorder. This may be done upon the ground I have mentioned without offering violence to humanity, or calling in question the sameness of descent, or natural equality of mankind. 3. Is the colour of the negroes a disease? Then let science and humanity combine their efforts, and endeavour to discover a remedy for it. Nature has lately unfurled a banner upon this subject. She has begun spontaneous cures of this disease in several black people in this country. In a certain Henry Moss, who lately travelled through this city, and was exhibited as a show for money, the cure was nearly complete. The change from black to a natural white flesh colour began about five years ago at the ends of his fingers, and has extended gradually over the greatest part of his

body. The wool which formerly perforated the cuticle has been changed into hair. No change in the diet, drinks, dress, employments, or situation of this man had taken place previously to this change in his skin. But this fact does not militate against artificial attempts to dislodge the colour in negroes, any more than the spontaneous cures of many other diseases militate against the use of medicine in the practice of physic. To direct our experiments upon this subject I shall throw out the following facts.—1. In Henry Moss the colour was first discharged from the skin in those places, on which there was most pressure from clothing, and most attrition from labour, as on the trunk of his body, and on his fingers. The destruction of the black colour was probably occasioned by the absorption of the colouring matter of the rete mucosum, or perhaps of the rete mucosum itself, for pressure and friction it is well known aid the absorbing action of the lymphatics in every part of the body. It is from the latter cause, that the palms of the hands of negro women who spend their lives at a washing tub, are generally as fair as the palms of the hands in labouring white people. 2. Depletion, whether by bleeding, purging, or abstinence, has been often observed to lessen the black colour in negroes. The effects of the above remedies in curing the common leprosy, satisfy me that they might be used with advantage in that state of leprosy which I conceive to exist in the skin of the negroes. 3. A similar change in the colour of the negroes, though of a more temporary nature, has often been observed in them from the influence of fear. 4. Dr. Beddoes tells us that he has discharged the colour in the black wool of a negro by infusing it in the oxygenated muriatic acid, and lessened it by the same means in the hand of a negro man. The land-cloud of Africa, called by the Portuguese Ferrino, Mr. Hawkins tells us, has a peculiar action upon the negroes in changing the black colour of their skins to a dusky gray. Its action is accompanied, he says, with an itching and prickling sensation upon every part of the body which increases with the length of exposure to it so as to be almost intolerable. It is probably air of the carbonic kind, for it uniformly extinguishes fire. 5. A citizen of Philadelphia, upon whose veracity I have perfect reliance,* assured me that he had once seen the skin of one side of the cheek inclining to the chin, and of part of the hand in a negro boy, changed to a white colour by the juice of unripe peaches, (of which he ate a large quantity every year,) falling, and resting frequently upon those parts of his body.

"To encourage attempts to cure this disease of the skin in negroes, let us recollect that by succeeding in them, we shall produce a large portion of happiness in the world. We shall in the *first* place destroy one of the arguments in favour of enslaving the negroes, for their colour has been supposed by the ignorant to mark them as objects of divine judgment, and by the learned to qualify

* "Mr. Thomas Harrison."

them for labour in hot, and unwholesome climates. *Secondly*, We shall add greatly to *their* happiness, for however well they appear to be satisfied with their colour, there are many proofs of their preferring that of the white people. *Thirdly*, We shall render the belief of the whole human race being descended from one pair, easy, and universal, and thereby not only add weight to the Christian revelation, but remove a material obstacle to the exercise of that universal benevolence which is inculcated by it."

OF LIFE.

The knowledge of the mode in which the various functions of the body are exercised constitutes the *science of life.* The manifestations of life have, consequently, been considered already. We have seen, that animal and vegetable substances possess the ordinary properties of matter, but that these properties are singularly controlled, so that organized bodies, are prevented from undergoing those changes, that inevitably occur so soon as they become deprived of vitality. The human body is prone to decomposition. It is formed of substances extremely liable to undergo putrefaction, and is kept at a temperature the most favourable for such change; yet so long as life exists, the play of the ordinary affinities is prevented, and this constant resistance to the general forces of matter prevails throughout the whole of existence, even to an advanced old age, when it might be supposed the vital forces must be enfeebled almost to annihilation. The case of solution of the stomach after death, described in the first volume of this work, is an additional and forcible evidence of such resistance. So long as life continues in the stomach, the gastric secretions exert no action on the organ, but, when life becomes extinct, the same secretions act upon it in the same manner that they do upon other dead animal matter. What, then, is this mysterious power, possessed of such astonishing, such incomprehensible properties?

Our knowledge is limited to the fact above stated, that organized matter, in addition to the general physical and chymical forces, possesses one other,—the *vital force* or *principle*, *vitality* or *life.* This principle exists, not only in the whole, but in every part, of a living body; and its existence is evidenced by the unequivocal signs afforded by the various functions, which we have considered, as well as by others to be presently described. Yet it is not equally evinced in all organs; some appearing to be possessed of more vitality than others,—a result probably produced by diversity of texture, as it would seem irrational for us to admit a different kind of vital principle, wherever its manifestations appear to be modified.

Admitting the existence of this controlling principle, what, it may be asked, are the functions through which it immediately acts in keeping up the play of the living machine? It has been elsewhere seen, that, in animals, the reciprocal action of innervation and circulation are indispensable, and that if one of these functions be arrested, the other quickly ceases. This is only applicable, however, to animals; and it has been doubted, whether it applies to all and to every part of them, whilst to the vegetable it is altogether inapplica-

ble, unless we regard it, with some physiologists, to possess a rudimental nervous system. The function of sensibility exhibits to us the mode in which the nervous system acts in connecting man with the objects around him, through the agency of volition; but numerous other acts take place within him, altogether uninfluenced by volition, and yet indispensable for the maintenance of existence. These last acts are equally met with in the animal and the vegetable; and hence a division has been made, by Bichat, into *animal life*, and *organic life*:—the former evidenced by those functions, that are peculiar to animals—sensibility and voluntary motion—which require the presence of a great nervous centre, that may receive from, and transmit to, the different parts of the body, the nervous irradiations,—the necessary excitant of the different functions:—the latter evidenced by those functions that are common to animals and vegetables, and are inservient to the nutrition of the frame,—as digestion, absorption, respiration, circulation, &c., all of which go on without any direct exercise of volition; and occasionally, it has been believed, independently of all nervous influence.

Physiologists may, on this point, be divided into two classes;—they who consider, that the whole of the organic functions are under the government of the nervous influence; and they who think that the nervous influence does not extend to all the organic functions, but only to the principal of them.

The supporters of the first opinion believe, that the agents, or conductors of the nervous influence, are less and less dependent upon the nervous centres, when such exist, the lower the animal is situated in the animal kingdom, and the lower the function; but they consider the nervous influence to be indispensable to every living being, and to every part of such being. In support of this opinion, they are of course compelled to believe, either that a nervous system exists in the vegetable, or that there is a system, which appears to exert over every part of it an influence necessary for its life, and which is, consequently, analogous to the nervous system of animals. The organ of this influence is, by some botanists, considered to be the *medulla* or *pith;* whence medullary appendages set out, to be distributed to every part of the vegetable, and which are particularly abundant, in such parts as are charged with very active functions,—as the flower. Brachet maintains this idea, and compares the knots of the pith to the ganglions of the nervous system,—destruction of the pith, and especially of these knots, occasioning the death of the parts, that receive their filaments from them. Dutrochet, again, considers, that *nervous corpuscles* exist in the pith of vegetables, which constitute the rudiments of a nervous system; but, in the vegetable, this system is diffused, instead of being collected in a mass, as in the animal.

The believers in the earlier formation of the nervous system in the fœtus will necessarily be in favour of the first opinion, and it would of course be strengthened if the results of the experiments of Dumas

on generation should be found correct, and if the spermatic animalcules, which, according to him, are the agents of fecundation, should be discovered to be the rudiments of the nervous system of the new individual, a circumstance, which, however, is as doubtful as the confirmation is difficult.

The supporters of the second opinion,—that the nervous influence does not extend to all the organic functions,—assert, that it is chiefly exerted on those functions, which are of the highest moment,—the most elevated in animality; that it is less and less in the inferior functions, and ultimately ceases in the lowest acts,—those that immediately accomplish nutrition and reproduction; and the arguments they adduce in favour of their views are, that these lowest acts exist in every living being—vegetable as well as animal; and that in the superior animal, and in man, there are many parts which do not appear to contain nerves. They, moreover, consider the nervous system as one superadded to living beings, not only for life, nutrition and reproduction, but also, where necessary, for sensation, motion, &c., and hence the prolongations or extensions of this system ought to be sent to the organs of the internal or nutritive functions, for the purpose of connecting them with the organs of the external or sensorial functions: and that it is in these connexions only that innervation consists. In this view, consequently, the nervous influence arises only from the necessity of connecting the organs; is but an indirect condition of life; exists in the upper animals only, and can in no way be invoked to account for vegetable life.

The last is, in our view, the most accurate opinion. We cannot, in the present state of knowledge, admit the existence of nerves in the vegetable: certainly no such thing as a nervous centre is discoverable, and yet we find the most complicated acts of nutrition and reproduction exercised by it, and the principle of instinct as strikingly evidenced as in many animals. We are, therefore, irresistibly led to the conclusion, that the manifestations of vitality are but little, if at all, connected with nervous influence, and that the nerves are added, in the upper animals and functions, for other purposes than that of directly communicating vital properties to the part. This deduction will be found confirmed by the facts to be hereafter mentioned, connected with the independence of the vital property of irritability of the nervous influence.

We have elsewhere alluded to the similarity between the nervous and galvanic fluids, and to the notion, which has prevailed of the similarity, if not identity, between the vital principle and electricity, as well as to the strange views of *endosmose* and *exosmose*, promulgated by Dutrochet, and which have been so happily commented on by Dr. J. K. Mitchell. The mode, in which Dutrochet assimilates the phenomena of animal and vegetable life to the actions of endosmose and exosmose, is as follows. It is known that the sap in vegetables ascends from the roots to the stalk; first, by the action of the *spongioles* or terminal buds of the roots, which are evidently organs

for the absorption and impulsion of the sap; and secondly, by the action of the leaves, which, by exciting an action of transpiration and evaporation at the top of the plant,—the greater in proportion to the warmth and dryness of the air,—exert a kind of aspiration on the sap received by the spongioles. These spongioles Dutrochet considers to be cellular organs containing organic fluids in their interior; and, consequently, they cannot be plunged into water, without the fluid penetrating by endosmose, not only into their interior, but even as far as the top of the stalk. Hence, according to Dutrochet, endosmose constitutes the action of absorption by the spongioles, and is the cause of the circulation of the sap. It presides, also, over the developement and nutrition, the movements of composition and decomposition, of plants; for as it consists of two opposite electric currents, it not only conveys fresh substances incessantly into the interior of the structures, and removes a part of those existing there, but also induces constant chymical modifications in the organic elements of parts;—every electrical action modifying the chymical nature of matter, as every chymical action induces a developement of electricity. It is also the agent of the secretions. The exhalation of vegetables is, according to him, no more a simple physical evaporation than their absorption is the effect of capillarity. It, also, is a phenomenon of endosmose. He does not doubt, that capillarity, gravity, agitation by the winds, &c. exert an influence on the functions of vegetables, but he considers such influence to be accidental, and the true vital motor to be the electrical agent. He regards the medulla or pith of vegetables to be to their organization what the nervous system is to the organization of animals, and to be intended to dispense everywhere the vital activity, or electricity.

As the conditions of endosmose,—namely, a vesicular structure and the presence of organic fluids denser than water in the vesicles,—exist in animals as well as in vegetables, Dutrochet invokes a similar influence in the case of the former as in that of the latter. In the same manner, as it occasions the progression of the sap in vegetables, it presides over the capillary circulation in animals, and especially over the progression of the blood in the veins, as well as over absorption, secretion, nutrition, &c. All these actions, however, take place by filtration through permeable, organic membranes,—all that has been said of the agency of the venous radicles in absorption, and of the arterial radicles in exhalation and nutrition, being, according to Dutrochet, physiological *mythi*. The sanguineous system constitutes a cavity devoid of outlet, and it is by filtration through the parietes of the vessels, which constitute it, that it receives, and parts with, its elements. In short, endosmose is the essence of the life of animals, and as it is an electrical phenomenon, electricity, Dutrochet concludes, is the motor of the life of animals, as it is of that of vegetables. He, moreover, extends his theory to pathology, asserting, that as endosmose is the vital act *par excellence* and as it is a phe-

nomenon of electricity, we may conceive that diseases may consist in some defect in endosmose or electricity, and that our therapeutical agents should be directed to the modification of such endosmose. Inflammation, for example, is, according to him, *hyperendosmose*.

It is obvious, that the foundations of a theory, so extensive in its ramifications, ought to be tested by accurate, and repeated investigation, and that no deductions can be considered established, until this has been accomplished, and the base found to be impregnable. This has not been done. On the contrary, many of the positions have been seriously assailed by Poisson and Mitchell, and even Dutrochet's own faith seems to have been shaken in his electrical theory.

The system of Bachoué de Vialer on innervation appears to rest on still less foundation. This, according to Adelon, is merely an application of the electro-chymical law of Becquerel, that, when two substances, made to communicate with each other by a conducting wire, simultaneously exert a chymical action with a third, a galvanic current is developed, which is always directed from the substance in which this action is strongest, towards that in which it is least. Now, says M. Bachoué, as the electric fluid is always evidenced during chymical action, and as in every organ, a simultaneous chymical action is constantly exerted by the transformation of arterial into venous blood, whilst by means of conductors,—the nerves,—the nervous centres communicate with every part of the organism,—in each nervous cord, a constant galvanic current must be established, proceeding from its central to its peripheral extremity, or conversely, according as the chymical action, whence the current emanates, predominates at the one or other extremity. This current, according to M. Bachoué, determines the play of each organ; and he explains, as follows, the mode in which it effects the different functions. *First.* The circulation being continuous in animals, an agent, which is developed in a continuous manner in their interior, must be looked for, as the cause of this function. This agent is the electric fluid, disengaged by the chymical action exerted simultaneously by the blood on the nervous centres, and on the organic tissues at the periphery; but as this action predominates in the centres, the galvanic current resulting from it is established from these centres towards the circulatory organs, and consequently the action of the latter is excited. To determine the current in this direction, nature occasions the afflux of blood to the ganglions of the great sympathetic to predominate,—these ganglions being, in his view, the nervous centres, that preside over the circulation. A greater chymical action is thus induced in the ganglions, and, of course, a more marked centrifugal galvanic current. This arrangement has likewise the advantage of diminishing the conducting power of the nerves, in accordance with the principle in physics, that the power of any body as a conductor of electricity is less in proportion as such body exerts a more powerful electro-motive action, whence it results, that the circulation is freed as much as possible from the perturbations, that

might otherwise be caused in it by the currents incessantly traversing the other parts of the nervous system—the cerebral and spinal nerves—with which those of the great sympathetic communicate. So that the action of the circulatory organs is constantly provoked by the centrifugal galvanic current, resulting from the chymical action exerted by the blood simultaneously in the nervous centres, and in the organs at the periphery of the body; whilst the uninterrupted arrival of the blood in the organs constantly excites in them, also, the chymical action necessary for the developement of the electricity, on which the continuity of the circulation is dependent. *Secondly.* M. Bachoué accounts, in the same way, for the mechanism of the *sensorial functions.* The contact between external agents and the sensitive, nervous extremities, renders the chymical action constantly produced by the contact of arterial blood there predominant; hence the production of a galvanic current passing from the circumference to the centre. This current excites the action of the brain to accomplish sensation; and the brain, excited by the process, becomes the seat of a more marked chymical action, which irradiates another, and a centrifugal, galvanic current to the muscles, that have to execute the movements.

According to Bachoué's theory, therefore, all the phenomena of life are derived from a chymical action which gives rise to the developement of electricity. He likewise extends his system to pathology. If the chymical action be comprised within due proportions, all the phenomena of life are performed in health; if, on the contrary, the proportions are inappropriate, disease results, which is always dependent on preternatural chymical actions giving rise to irregular galvanic currents.

The remarks, made regarding the views of Dutrochet, are equally applicable to those of Bachoué. Their very foundation, indeed, has been assailed by the experiments of M. Pouillet, at the Hôpital Saint Louis, of Paris, which contradict the existence of the centrifugal or centripetal galvanic currents, developed in the organs during the production of the vital phenomena.

The opinions of Raspail resemble somewhat those of Dutrochet. He wisely, however, expresses his ignorance of the cause of life; but he attempts to lay down a law of vitality and organization, which he likens to the algebraic unknown sign $\underline{x}$; and, who knows, says he, but experience may one day demonstrate, that this law is nothing more than electricity in movement applied to a certain order of phenomena? All the effects of the organization and elaboration of organs he ascribes to the property, which the organic vesicle possesses of aspiring gases and liquids, of condensing the gases with the liquids within it; of assimilating the products by attraction, and of rejecting or expiring, by repulsion, the products that do not admit of assimilation; but it is obvious, that this does not throw additional light on the obscure subject which we are investigating.

In the introductory remarks to the first volume of this work, the characters, which distinguish organized from inorganic bodies, were pointed out. All the characters of the former result from the influence of the vital principle, which produces the body of a definite magnitude, shape, structure, composition and duration. There is, moreover, a power, possessed by bodies, endowed with the living principle, of being acted upon by certain stimuli, and of being thrown into movement without the participation of the will. This has, indeed, by some physiologists, been considered to be the sole vital property,—with what truth we shall see hereafter. An inquiry into its manifestations will aid us materially in determining whether or not the vital principle is effected directly through the medium of the nerves, and will tend to confirm an opinion which we have already expressed on this subject.

Prior to the time of Haller the nervous system was looked to as the great source of power in the body; and the contractile power of the muscles,—described at length under the head of MUSCULAR MOTION,—was considered to be wholly derived from the nerves, which were supposed to transmit the power to the muscular fibre as it was called for,—accurately regulating the quantity supplied.

Haller contended for a *vis insita*, a power of *irritability* or *contractility*, essentially residing in the muscles themselves, independently of any condition of the nervous system, and called into action by stimuli, of which, in the case of the voluntary muscles, the nervous influence is one, contributing, however, like all other stimuli, to exhaust it, instead of furnishing any fresh supply. We have elsewhere shown, that a muscle is capable of being thrown into contraction after a limb has been removed from the body, and for a considerable period after the cessation of respiration, circulation, and consequently of innervation, provided the appropriate stimuli be applied, so as to excite the vis insita, which remains attached to the muscle for some time after dissolution; and if all the nerves, supplying the limbs of a frog, be divided, and cut out close to the place where they enter the muscles, the muscles will still retain their contractility in as great a degree as when the nerves were entire.

They, who believe that the contractility of muscles is wholly derived from the nervous system, maintain, however, that, in such case, the stimulus may still act, through the medium of the portions of nerves that must always remain attached to the muscle, however carefully attempts may have been made to remove them; and some have supposed, that these nervous fibres may even constitute an essential part of the muscular fibre. The most satisfactory reply, that has been made to this argument, is the following experiment of Dr. Wilson Philip. All the nerves, supplying one of the hind legs of a frog, were divided, so that it became completely paralytic. The skin was removed from the muscles of the leg, and salt sprinkled upon them, which, being renewed from time to time, excited contractions in them for twelve minutes: at the end of this time, they

were found no longer capable of being excited. The corresponding muscles of the other limb, in which the nerves were entire, and of which, consequently, the animal had a perfect command, were then laid bare, and the salt applied to them in the same way. In ten minutes, they ceased to contract, and the animal had lost the command of them. The nerves of this limb were now divided, as those of the other had been, but the excitability of the muscles to which the salt had been applied was gone. Its application excited no contraction in them. After the experiment, the muscles of the thighs in both limbs were found to contract forcibly on the application of salt. It excited equally strong contraction on both sides. In this experiment, the excitability of the muscles, whose nerves were entire, was soonest exhausted; and hence Dr. Philip properly concludes, that the nervous influence, far from bestowing excitability on the muscles, exhausts it like other stimuli; and that the excitability or irritability is a property of the muscle itself.

It seems that this essential characteristic of living bodies is a distinct vital property, not confined, as Haller supposed, to the muscular structure, but existing over the whole body. In favour of its not being dependent upon the nerves, we have the fact of its presence in the vegetable as well as in the animal. Many plants exhibit this power in a remarkable manner. The barberry bush is one of these. In this flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament near the bottom. The irritability of that part is such, that the filament immediately contracts there, and consequently strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this effect, provided no concussion be given to the whole. After a while, the filament retires gradually, and may be again stimulated; and when each petal, with its annexed filament, is fallen to the ground, the latter, on being touched, shows as much irritability as ever.

In another plant,—the *Cistus helianthemum*, *dwarf cistus* or *lesser sunflower*,—the filaments, when touched, execute a motion, the reverse of that of the barberry. They retire from the style and lie down, in a spreading form, upon the petals.

Owing to the possession of this property, the *Apocynum androsæmifolium* or *dogs-bane* is extremely destructive to insect life. Attracted by the honey on the nectary of the expanded blossom, the instant the trunk of the fly is protruded to feed on it, the filaments close, and, catching the fly by the extremity of its proboscis, they detain the insect until its struggles end in death, occasioned apparently by exhaustion alone. The filaments then relax, and the body falls to the ground.

These are only evidences, however, of particular parts possessing an unusual degree of irritability. The property exists in every part of the plant, and, as in the animal, is the essential characteristic of the principle of life.

Irratibility or contractility forms a medium of communication between the various parts of the living machine, and is excited to action by extraneous influences. All its movements, however, appear to be dependent upon the action of appropriate stimuli, and are, consequently, *passively* exercised.

There is a power, which has been conceived to be nearly allied to irritability, and is highly characteristic of organized bodies,—vegetable as well as animal,—whose movements or impulsions are *active*, and most varied. To this power, the term *instinct* has been appropriated by Virey, Fleming, Good and others. It is an extension of the ordinary acceptation of the term, but it enables us to understand the phenomena better than where we restrict it to those manifestations of man, or animals that bear the semblance of reason. It is this power, which, according to those gentlemen, regulates the movements, that are requisite to obtain a supply of food, to remove or counteract opposing obstacles, and to fly from impending danger, or repair injuries. "In every organized system," says Dr. Good, "whether animal or vegetable, and in every part of such system, whether solid or fluid, we trace an evident proof of that controlling, and identifying power, which physiologists have denominated, and with much propriety, the principle of life. Of its cause and nature we know no more than we do of the cause and nature of gravitation, or magnetism. It is neither essential mind nor essential matter; it is neither passion nor sensation; but though unquestionably distinct from all these, is capable of combining with any of them; it is possessed of its own book of laws, to which, under the same circumstances, it adheres without the smallest deviation; and its sole and uniform aim, whether acting generally or locally, is that of health, preservation, or reproduction. The agency, by which it operates, is that which we denominate or should denominate instinct, and the actions, by which its sole and uniform aim is accomplished, are what we mean or should mean by instinctive actions; or, to speak somewhat more precisely, instinct is the operation of the living principle, whenever manifestly directing its operations to the health, preservation, or reproduction of a living frame, or any part of such frame. The law of instinct, then, is the law of the living principle; instinctive actions are the actions of the living principle; and either is that power, which characteristically distinguishes organized from unorganized matter, and pervades and regulates the former, uniformly operating by definite means in definite circumstances to the general welfare of the individual system or of its separate organs, advancing them to perfection, preserving them in it, or laying a foundation for their reproduction, as the nature of the case may require. It applies equally to plants and to animals, and to every part of the plant, as well as to every part of the animal, so long as such part continues alive. It is this which maintains, from age to age, with so much nicety and precision, the distinctive characters of different kinds and species, which carries off the waste

or worn out matter, supplies it with new, and in a thousand instances, suggests the mode of cure, or even effects the cure itself, in cases of injury or disease. It is 'the divinity that stirs within us' of Stahl, the *vis medicatrix naturæ* of Hoffmann and Cullen and the physicians of our own day, &c. &c."

Of the existence of this instinctive principle we shall adduce a few examples from both the vegetable and the animal kingdom. When the seed of a plant is deposited in the ground, under circumstances favourable for its developement, it expands, and the root and stem are evolved. The root descends into the ground, manifestly not from the laws of gravitation, but owing to some inherent force, inasmuch as it penetrates the earth, which is of much greater specific gravity than itself. The stem, too, bursts through the earth, and rises into the atmosphere, notwithstanding that the air is of much less specific gravity, until, having attained the height to which the action of the vital principle limits it, its upward developement ceases. It rarely happens, however, that the root is capable of procuring nourishment sufficient for its future developement in immediate contact with it. It, therefore, sends out numerous filamentous radicles in all directions to search after food, and to convey it to the proper organs. The number and direction of these filaments, and the distance to which they extend, are regulated by the necessities of the plant, and the supply of the soil. A strawberry offset, planted in sand, will send out almost all of its runners in the direction in which the proper soil lies nearest, and few, and sometimes none, in the direction in which it lies most remote.

When a tree, which requires much moisture, has sprung up, or been planted in a dry soil, in the vicinity of water, it has been observed, that a much larger portion of its roots has been directed towards the water, and that, when a tree of a different species, and which requires a dry soil, has been placed in a similar situation, it has appeared, in the direction given to its roots, to have avoided the water, and moist soil. When a tree, too, happens to grow from seed on a wall, it has been seen, on arriving at a certain size, to stop for a while, and to send down a root to the ground. As soon as this root has been established in the soil, the tree has continued increasing to a large magnitude. The fact has been often noticed with respect to the ash,—a tree, which, in consequence of the profusion of its seed, is found more often scattered in wild and singular places, than any other not propagated by the agency of birds, or conveyed by the winds.

We find, in all cases, that if the roots of a plant, spreading in search of nourishment, meet with interruption in their course, they do not arrest their progress, but either attempt to penetrate the opposing body, or to avoid it by altering their direction. Dr. Fleming states, that he has repeatedly seen the creeping root of the *Triticum repens* or *couch grass*, piercing a potato, which had obstructed its

course. It is well known, too, that roots will pass under a stone wall or a ditch, and rise up on the opposite side.

A striking case of this nature was communicated to the author, by his venerable friend—Ex-President Madison. The wooden pipes, for the conveyance of water to Mr. Madison's establishment, having become obstructed, they were carefully examined, when it was found, that the roots of a honeysuckle, growing immediately above a plug, made of the wood of the *Liriodendron tulipifera* or *American poplar*, which is of a soft consistence, had penetrated the plug in various places to reach the water, and formed an agglomerated mass in the pipe so as to completely preclude the passage of the water along it.

The nearest approximation to these manifestations of instinct, in the animal, occur in the formation of the new being, and in the first actions that take place after birth. From the moment of the admixture of the substances, furnished by the parents at a fecundating copulation, there must be a principle existing in the embryo, which directs the construction and arrangement of its organs after a definite manner, and always according to that peculiar to the species. In the egg this is seen in the most distinct manner. The germ of the chick is surrounded by the nourishment requisite for its formation. Organ after organ becomes successively evolved, until the full period of incubation is accomplished, when it breaks the shell. At this time, it has within it a portion of nutriment derived from the yolk drawn into the body. This supplies its wants for a short period; but it soon becomes necessary that it should select and collect food for itself, and we observe it throwing its various organs into action for the prehension, mastication, deglutition, &c. of the food, as if it had been long accustomed to the execution of these functions.

In the formation of the human fœtus in utero the same instinctive action is observable in the successive evolution of organs, and in the limitation of the body to a determinate shape, size, structure, &c.; and when these requisites have been attained, the child bursts the membranous envelope, and is extruded, to maintain thenceforth an existence independent of the mother. More helpless, however, than the young of the animal kingdom in general, the infant requires the fostering care of the parent for the purpose of supplying it with the necessary nutriment, but as soon as food is conveyed to the lips, the whole of the complicated process of deglutition is effected for the first time, with the same facility as after long practice. As we descend in the animal kingdom, we find these inward actions constituting the instinct more and more largely exhibited. In the quadruped, it is not necessary, that the nipple should be applied by the mother to the mouth of the new-born animal. It is sought for by the latter, invariably discovered, and as invariably seized hold of, by the appropriate organ of prehension—the mouth. The lips are applied; the air is exhausted; and the milk flows according to exact

principles of hydrostatics, but without the animal having the least knowledge of the physical process which it accomplishes. Naturalists, indeed, assert, that before the calf has been more than half extruded from the mother, it has been seen to turn round, embrace, and suck the maternal teat.

As we descend still farther in the scale of creation, we discover the manifestations of instinct yet more signally developed; until ultimately, in the very lowest classes of animals, the functions are exercised much in the same manner as in the vegetable; and appear to be wholly instinctive, without the slightest evidence of that intelligence, which we observe in the upper classes of the animal kingdom, and pre-eminently in man. This, however, applies only to the very lowest classes; for, a short way higher up the scale, we meet with apparent intelligence, united with instinct, in a manner that is truly surprising and mysterious.

Again, the similarity of the actions of the instinctive principle, in the animal and vegetable, is exhibited by the reparatory power which both possess when injuries are inflicted upon them. If a branch be forcibly torn from a tree, the bark gradually accumulates around the wound, and cicatrization is at length accomplished. The great utility of many of our garden vegetables,—such as spinach, parsley, cress, &c.—depends upon the possession of a power to repair injuries, so that new shoots speedily take the place of the leaves that have been removed: similar to this is the reparatory process, instituted in the lobster that has lost its claw, in the water-newt that lost an extremity, or the eye; in the serpent deprived of its tail, and in the snail, that has lost its head. These parts are reproduced as the leaves are in the spinach or the parsley.

Few animals, however, possess the property of restoring lost parts; whilst all are capable of repairing their own wounds when not excessive, and of exerting a sanative power, when labouring under disease. If a limb be torn from the body, provided the animal does not die from hemorrhage, a reparatory effort is established, and if the severity of the injury does not induce too much irritation in the system, the wound will gradually fill up, and the skin form over it. To a lesser extent we see this power exerted in the healing of ordinary wounds, and in cementing broken bones; and although it may answer the purpose of the surgeon to have it supposed, that he is possessed of healing salves, &c., he is well aware, that the great art, in these cases, is to keep the part entirely at rest, whilst his salves are applied simply for the purpose of keeping the wound moist; the edges in due apposition, where such is necessary, and extraneous bodies from having access to it,—his trust being altogether placed in the sanative influence of the instinctive power situated in the injured part, and in every part of the frame.

It is to this power, that we must ascribe all the properties, assigned to the famous *sympathetic powder* of Sir Kenelm Digby,—which was supposed to have the wonderful property of healing

wounds, when merely applied to the bloody clothes of the wounded person, or to the weapon that had inflicted the mischief;—a powder, which, at one time, enjoyed the most astonishing reputation. The wound was, however, always carefully defended from irritation by extraneous substances; and it has been suggested, that the result furnished the first hint, which led surgeons to the improved practice of healing wounds by what is technically called the *first intention*. It is to this instinctive principle, so clearly evinced in surgical or external affections, but, at times, not less actively exerted in cases of internal mischief, that the term *vis medicatrix naturæ* has been assigned; and whatever may be the objections to the views entertained regarding its manifestations in disease, that such a power exists can no more be denied than that organized bodies are possessed of the vital principle. We have too many instances of recovery from injuries, not only without the aid of the practitioner, but even in spite of it, to doubt for a moment, that there is, within every living body, a principle, whose operations are manifestly directed to the health and preservation of the frame, and of every part of such frame.*

So far, then, it is manifest, that the instinctive actions of the animal and the vegetable are exerted according to the same laws, and probably through similar organs. This, at least, applies to the lowest of all animated beings, where the difference between them and the vegetable is small indeed. It applies equally to the human fœtus, which can be considered but to vegetate during the greater part of utero-gestation; and even for some time after birth its actions are purely instinctive, and differ but little from those of the vegetable, except that, owing to the organization of its nervous system, the acts are of a more complicated character. It is only when the brain has become duly developed, and the external senses fully so, that it exhibits so decidedly the difference between those acts, which it had previously accomplished instinctively, and the elevated phenomena of sensibility, which man enjoys so pre-eminently, but which are likewise possessed, to a greater or less extent, by the whole animal creation.

The difficulty, which occurs in pointing out the exact difference between the manifestations of instinct and those of intelligence, has induced some individuals to deny to animals the possession of the former. We have seen the mode in which the principle is evidenced in the zoophyte and in the vegetable; and it is but an extension of it, that we witness in the beings still higher in the scale. Yet how wonderful and inexplicable are its operations; and how forcible its impulsion in those minute animals, that surprise us by the ingenuity and forethought with which all their actions, for the preservation and reproduction of the species, are directed! Let us take a well-known example, from the many afforded by the insect tribe.

* See the author's 'General Therapeutics,' chap. I. Philad. 1836.

The cells of the ordinary honey-comb are intended for the larvæ of the different varieties of the occupants of the hive. These cells are usually placed horizontally, with their mouths opening towards the sides of the hive. The bottom of the cells, instead of forming one flat square, is composed of three lozenge-shaped pieces, so united as to make the cell end in a point; consequently, the whole forms an hexagonal tube, terminating in a pyramidal cavity. If the two cells had been a single hexagonal tube, intersected in the middle by an flat, instead of a pyramidal, division, not only would the shape not have answered the purpose of the bees, but more wax would have been expended in its construction. Hence, it would seem, that both the body and the base of the tube are adapted for their object; that the greatest strength and the greatest capacity are obtained with the least expenditure of wax in an hexagonal tube with a pyramidal base.

Réaumur, when inquiring into the habitudes of these industrious animals, requested König, an able mathematician, to solve the following question:—among all the hexagonal tubes with pyramidal bases, composed of three similar and equal rhombs, to determine that which, having the same capacity, can be constructed with the least possible quantity of matter? König, not aware of the precise object of Réaumur's inquiry, solved the problem, and found,—that if three rhombs or lozenges were so inclined to each other that the great angles measured 109° 26′, and the little angles 70° 34′, the smallest possible quantity of matter would be needed. Maraldi measured the angles actually formed at the bottom of a cell, and found that the great angles gave 109° 28′, and the little 70° 32′. All this, however, may be ascribed to blind instinct, proceeding uniformly in the same track, without any evidence of the admixture of reason; but we have innumerable instances, in the same insects, to show, that their operations are varied according to circumstances, and that intelligence is manifestly expended in the adaptation of their means to definite purposes. Of this we shall give but one example. Hüber, whose inquiries into this part of entomology have been singularly minute and accurate, having had great ravages committed on his hives by the *sphinx atropos* or *death's-head moth*, determined to construct a grating, which should admit the bee but not the moth. He did so, and the devastation ceased. He found, however, that in other hives, not protected by his agency, the bees had adopted a similar expedient for their defence; and these defences were variously constructed in different hives. "Here, was a single wall whose opening arcades were disposed at its higher parts; there, were several bulwarks behind each other, like the bastions of our citadels: gateways, masked by walls in front, opened on the face of the second rows, while they did not correspond with the apertures of the first. Sometimes, a series of intersecting arcades permitted free egrees to the bees, but refused admittance to their enemies. These fortifications were massy, and their substance firm and compact, being composed of propolis and wax." It would be endless, however, and beyond the design of

this work, to enumerate the various evidences of intelligence, exhibited by the insect tribe, in fulfilling the ends for which they have been destined by the Great Author of nature.

In all our reasonings on the subject of instinct, we must be compelled to admit, in the case of most animals at least, a union of intelligence that strikingly modifies those actions,—the impulse to which is doubtless laid in organization. The precise line of demarcation between instinctive acts and reason cannot, however, be established, and this has led some philosophers to call in question the existence of the former.

It is owing to this union of intelligence with instinct, that we find animals accommodating themselves to circumstances, so that if prevented from adopting the habits that belong to the species, they have recourse to others as similar as possible. Thus, if a bird is prevented from building its nest in a particular situation, or from obtaining the material, which birds of its own species employ, it has recourse to other materials and to another situation, as like those that are appropriate to it as is practicable.

The rook usually and instinctively builds its nest on the summit of the tallest trees: but Dr. Darwin,—who is one of those that call in question the influence of instinct,—asserts, that in Welbourn churchyard, a rookery was formed on the outside of the spire, and on the tops of the loftiest windows. There had formerly been a row or grove of high trees in the neighbourhood, which had been cut down, and, in consequence, the birds exhibited the union of intelligence with instinct, by building on the lofty spire and windows. In like manner, the jackdaws of Selbourn, according to Mr. White, not finding a sufficiency of steeples and lofty houses, on which to hang their nests in that village, accommodated themselves to circumstances, and built them in forsaken rabbit burrows.

By Stahl, and the animists in general, as well as by more recent philosophers, the whole of the phenomena of instinct have been referred to experience, so obscure as not to be easily traceable, but not the less certainly existent. The insect tribes, however, furnish us with many cases where the young being can never see the parents, and can, of course, derive no benefit from the experience of its progenitors. Yet their habits are precisely what they have probably ever been;—so uniform, indeed, as to compel us to refer them to some constant impulse connected with their special organization, and consequently instinctive.

In support of the existence of these natural impulsions, the common occurrence of a brood of young ducks, brought up under a hen, has been adduced. These little beings, soon after they have broken the shell, and contrary to all the feelings and instincts of the foster mother, will seek the water, and suddenly plunge into it, whilst the hen herself does not dare to follow them. By what kind of experience or observation,—it has been asked,—by what train of thought or reasoning has the scarcely fledged brood been able to discern that

a web-foot adapts them for swimming? Any experience they can have derived must have taught them to shun the water; yet, notwithstanding this, instinct points out to them the habitudes to which they are adapted, and its indications are obeyed in spite of every kind of counter-experience.

Attempts have occasionally been made to domesticate the *wild turkey* of this continent, by bringing the young up under the common turkey, but they have always resumed the way of life to which instinct has directed them, when opportunity offered; in accordance with the Horatian maxim:

"Naturam expellas furcâ, tamen usque recurret."

Mr. Madison reared, with great care, a young hawk, which, for a long time, associated with the young of the poultry, without exhibiting the slightest carnivorous or migratory propensity, until, on one occasion, whilst some of his friends were admiring its state of domestication, it suddenly rose in the air, darted down, and seized a chicken, with which it flew to a neighbouring tree, and, after it had finished its repast, took flight, and was never seen afterwards.

Instinct, then, is possessed by every organized body, animal and vegetable; whilst intelligence is the attribute of those only, that are endowed with a certain nervous developement. They are, therefore, manifestly distinct;—the former predominating over the latter in the lower classes of animals; whilst, in the upper classes, intelligence becomes more and more predominant, until ultimately, in man, it is so ascendant as to appear to be the main regulator of the functions; indeed, some have altogether denied the existence of instinct in him. Instinct is seated in every part of a living body; is totally independent of the nervous system; occurs in the vegetable and the zoophyte unprovided with nerves, or at least in which nerves have never been discovered; whilst intelligence is always accompanied by a nervous system, without which, indeed, its existence is incomprehensible. How can we, consequently, accord with those physiologists who place the seat of instinct in the organic nervous system; whilst that of intelligence is in the brain? Where is the organic nervous system of the zoophyte, and *a fortiori* of the vegetable? Or how can we admit the seat of the various instincts, with Gall, to be in the brain, seeing that we have them exhibited where there is no brain nor anything resembling one. The acephalous fœtus undergoes its full developement in other respects in utero, with the same regularity, as to shape and size, as the perfect fœtus, and can we deny it the existence of instinct? Yet, in the upper classes of animals especially, many of the manifestations of instinct are effected through the nervous system, which, in them, as we have elsewhere seen, seems to hold in control the various functions of the frame, and to be one of the two great requisites for the existence of vitality. The instinctive action in the appropriate organ, which gives rise to the internal sen-

sations of hunger, thirst, &c., is communicated to the great nervous centres by the nerves, and the brain responds to the impression, and excites, through the medium of the nerves, the various organs into action which are calculated to accomplish the monitions of the instinct.

What is the nature of this instinctive property? Of this we know no more than we do of the principle of life, of which it is one of the manifestations. It is equally inscrutable with the imponderable agents, light, caloric, electricity, or magnetism, or with the mode of existence of the immaterial principle within us, which gives rise to the mental phenomena: we see it only in its results; which are, in many cases, as unequivocal as those produced by the agents just referred to. All, perhaps, that we are justified in concluding is—with Dr. Good—that instinct is the operation of the principle of organized life, by the exertion of certain *natural* powers, directed to the present or future good of the individual, whilst reason is the operation of the principle of intellectual life, by the exercise of certain *acquired* powers directed to the same object; that the former appertains to the whole organized mass as gravitation does to the whole unorganized; actuating alike the smallest and the largest portions; the minutest particles and the bulkiest systems; and every organ, and every part of every organ, whether solid or fluid, so long as it continues alive; that, like gravitation, it exhibits, under particular circumstances, different modifications, different powers, and different effects; but that, like gravitation, too, it is subject to its own division of laws, to which, under definite circumstances, it adheres without the slightest deviation; and that its sole and uniform aim, whether acting generally or locally, is that of perfection, preservation or reproduction.

In this view, *reason* demands discipline, and attains maturity; *instinct*, on the contrary, neither requires the one, nor is capable of attaining the other. It is mature from the first, and equally so in the infant as in the adult.

The great cause of all those mysterious phenomena, which characterize living bodies, and distinguish them by such broad demarcations from the dead, has been a theme of anxious inquiry in all ages; and has ever ended in the supposition of some special abstract force, to which the epithet *vital* has been assigned, and which has received various appellations. Hippocrates designated it by the terms φυσις, and ενορμων; Aristotle styled it the *animating* or *motive and generative principle;* Van Helmont, the *archæus;* Stahl, *anima;* Barthez, and Hunter, *vital principle*, &c. &c. Yet, as Dr. Barclay has correctly observed, all physiological writers,—ancient and modern,—seem to be agreed, that the causes of life and organization are utterly invisible, whether they pass under the name of animating principles, (Aristotle, Harvey, &c.) vital principles, (Barthez,) indivisible atoms, spermatic powers, organic particles or organic germs, (Buffon,) formative appetencies or formative propensities, (Darwin,)

formative forces, (Needham,) formative nisus or bildungstrieb, (Blumenbach,) pre-existing monads, (Leibnitz,) semina rerum, (Lucretius,) plastic natures, (Cudworth,) occult qualities, or certain unknown chymical affinities. "All seem agreed, that whatever they be, they have been operating since the world began, and throughout the world operating regularly, without intermission, in various places at the same time. All seem agreed, that their modes of operation are strictly methodical; that they seem to act on definite plans, and actually exhibit specific varieties of chymical combination, and mechanical structure, which human intelligence cannot comprehend, much less explain. From their mutual dependence, and other relations subsisting between them, all seem to speak as if they were subject to one great cause, which regulates and harmonizes the whole. All seem to speak of this great cause as if it were eternal, omnipotent, omnipresent: whether it be the element of fire, of air, or of water, or whether it be fate, nature, necessity, or a God."

By virtue of this principle of life, every organized tissue is possessed of certain *properties*, to which the term *vital* has been assigned. Regarding the precise number of these properties, physiologists are not agreed. Whilst some have reckoned many; others have admitted but one. All the functions, which we have hitherto considered, are under the influence of life, and are products of the vital properties seated in the tissues; but we do not consider them to be directly caused by these properties. Digestion, for example, is executed by a series of organs, all of which are conducive to a certain result, the aggregate constituting the function of digestion. The result of the action of the salivary gland is very different from that of the liver; yet both operations are vital, but modified by the different organization of the two glands. We do not ascribe the difference to a difference in the *vital properties* of the glands. They are probably the same in both; and are seated in the primary tissues, of which all the more compound textures and organs are built up. They are primary or fundamental properties of living matter.

Stahl, having observed obscure, oscillatory movements, alternate contraction and expansion in certain parts of the body, either during the exercise of a function, or on the application of some external agent, conceived, that every part of the frame is, at all times, more or less susceptible of similar movements. These movements he called *tonic*, their effect upon the organs *tone*, and the property by which they were induced he esteemed peculiar to organization, and termed it *tonicity*. This vital property, he conceived, influences the progression of the fluids in the vessels; the phenomena of exhalation and absorption, and is totally distinct from the properties possessed by inorganic bodies.

Haller admitted two vital properties, very different from each other, which seemed to him to be equally elementary. The one of these is that by which a living part exhibits itself to be *sensible*, or transmits to the sensorium an impression made upon it, either by an

extraneous body, or by its own internal and organic action; the other, that by which a part contracts in a manner appreciable to the senses, either by the influence of the will, or of some external or internal stimulus. The first of these he considered to be a special vital property, which he termed *sensibility;* and the second to be another property, which he called *irritability.* Prior to his time, the word irritability had been adopted by Glisson, who had noticed the fact, that living matter was acted upon by *irritants* of various kinds, in a mode nowise analogous to physical and chymical motions, and hence he concluded, that every organ of the human frame possesses an inherent and peculiar force, which presides over its movements, and is requisite for the exercise of its functions. This force he called *irritability.* Von Gorter subsequently extended the views of Glisson, and applied them to the vegetable, affirming irritability to be the sole vital property of all organized bodies, vegetable as well as animal.

The acceptation, given to the term by Haller, was consequently more limited. He restricted it to those motions of parts which fall under the observation of the senses; such as the contraction of the voluntary muscles, heart, &c. He made numerous experiments on living animals, for the purpose of discovering what parts are possessed, or not, of the two properties of *sensibility* and *irritability,* and he concluded, that the former resides exclusively in the nervous,—the latter in the muscular, system.

This celebrated theory, which formed so large a part of physiological science at one time, and is still an interesting topic to the physiologist, has been referred to in so many parts of this work, as to require but few comments in this place. We have seen, that many of the parts, regarded by Haller as insensible, are acutely sensible in disease, and that we cannot pronounce a part to be positively insensible, until we have applied every kind of irritant to it without effect. We have elsewhere defined sensibility to be an exclusive property of the nervous system; and have attempted to show, that irritability is a property of the muscular tissue—a *vis insita*—totally independent of the nerves, but of which the nervous fluid is an appropriate excitant. As, however, the vital properties of sensibility and irritability were restricted by Haller to the nervous and muscular systems, they were regarded to be insufficient for the explanation of the various living actions of the frame: the next step was, to extend them to every part and to every tissue. It was found, for example, that on investigating the most minute movements of parts, these movements were always preceded by an impression, to which they seemed sensible, and which appeared to excite their actions. This general property, common to every living part, of receiving an impression, was called *sensibility;*—thus generalizing the property, which Haller had restricted to perceptivity by the mind. Every part was said to be *sensible* to the blood sent to it for its nutrition. Again, every part was observed to move in consequence of the im-

pression it received, sometimes in an apparent manner,—as the heart; at others, too slightly for its movements to be recognized otherwise than by the results,—as in the case of the glandular organs; but always in a manner special to organized matter, and not analogous to any physical or chymical process. This motion was, therefore, referred to another force, called *motility*, which was nothing more than irritability generalized. These two properties are alone admitted by most modern writers. Every organ is said to *feel* and to *move*, after its manner, in the performance of its function;—the stomach in digestion; the heart in propelling the blood; the muscle in contracting, and the nerve in transmitting sensitive impressions to the brain.

Many modern physiologists, whilst they admit the properties of sensibility and motility, have reckoned a greater number of vital properties; and this owing to their having observed that each part has its own peculiar mode of sensibility and motility, and when these modes have seemed to differ largely from each other, they have elevated them into so many special, vital properties. The chief modern theories on the vital properties are those of Barthez, Blumenbach, Chaussier, Dumas, and Bichat. Barthez admitted five, which we can do no more than enumerate,—*sensibility*, *force of contraction*, *force of expansion* or *active dilatation*, *force of fixed situation*, and *tonicity*. Blumenbach also admitted five;—*sensibility*, *irritability*, *contractility*, *vita propria* or *proper force of life*, and *nisus formativus*, *force of formation* or b i l d u n g s t r i e b. Dumas referred all the living phenomena to four vital properties; *sensibility*, *motility*, *force of assimilation*, and *force of vital resistance*.

The theory of Bichat on this subject requires a more detailed notice. He, also, admitted five vital properties; *organic sensibility*, *insensible organic contractility*, *sensible organic contractility*, *animal sensibility* and *animal contractility*. *First. Organic sensibility* is the faculty, possessed by every living fibre of receiving an impression, or of being modified by contact, so that the modification is restricted to the part that experiences it, and is not transmitted to the brain. The term *sensibility* was adopted by Bichat, because already established, and the epithet *organic* was added, to affirm, that it is the exclusive attribute of organized bodies, and common to all. This property is not only modified in each organ—as the difference in their nutrition and functions demonstrates—but it adapts each organ to its appropriate external stimulant, so that the salivary gland shall be specially influenced by mercury; the upper part of the small intestine by calomel; the lower by aloes, &c. &c. Its exercise is continuous, involuntary, known only by its results, and is more marked as we descend in the scale of animal life; whilst animal sensibility is the contrary. *Secondly. Insensible organic contractility* is the faculty, possessed by every living part, of moving in an imperceptible manner, in consequence of an impression immediately received, without either the mind having consciousness of the motion, the will partici-

pating, or the brain in any manner directing it. We have an example of this in the action of the stomach during digestion; and of every part of the body on the blood sent to it for its nutrition. Bichat applied the term *insensible organic contractility* to this property, for the following reasons;—*contractility*, because contraction is the kind of motion, which constitutes it; *organic*, because it is common to all living beings; and *insensible*, because the brain has no consciousness of it. Like organic sensibility, it is modified in each organ. Its exercise is likewise continuous and involuntary; and it also exhibits itself more intensely as we descend in the scale of beings. It always co-exists with organic sensibility. *Thirdly. Sensible organic contractility* is the same motive faculty as the last, with this difference, that the movements induced by it fall under the senses, and are recognized independently of their results. This property is likewise modified in each organ; its exercise is also involuntary, and it only differs from the last in degree,—the movement that constitutes it being apparent. Thus, the heart contracts independently of the will, but its motions are not imperceptible, as in the cases which belong to the second vital property of insensible organic contractility. *Fourthly. Animal sensibility* is the property possessed by certain organs of transmitting to the mind, through the medium of the brain, the consciousness of impressions, which they have received. It is sensibility in the restricted acceptation of Haller. The epithet *animal* was given to it by Bichat to distinguish it from the other variety of sensibility, which belongs to all organized bodies, whilst this is exclusively possessed by animals. The whole of the attributes of this property have been detailed, at much length, in the first volume of this work. *Fifthly.* Bichat admitted a fifth vital property, under the name *animal contractility*, which comprised voluntary muscular contraction;—treated of elsewhere as one of the functions of the body. It differs from organic contractility, in its exciting cause not being seated in the organ in which it is developed,—that is, in the muscle,—but in the brain; and, moreover, whilst the other varieties of contractility are irresistibly connected with, and proportioned to, the kind of sensibility correspondent to them, this is not the case with animal sensibility, and its play is never continuous.

From the distinction we have endeavoured to draw, between the fundamental vital properties and the functions, it will be obvious, that the ingenious division of Bichat is susceptible of farther curtailment by analysis. A vital property must be one possessed by all living bodies; it is fundamental in the tissues, and differs according to the precise structure of the tissue. It is found in the vegetable, as well as in the animal. Neither of the two last properties of Bichat, however, corresponds with this definition. They do not exist in the vegetable. They require not only a nervous system, but a brain, that can conceive and will. They are both, indeed, complicated functions, and, as such, have been considered at great

length elsewhere. By ultimate analysis, therefore, the five vital properties of Bichat may be reduced to the two we have previously mentioned,—*sensibility* and *motility*. Perhaps we ought to rest satisfied with the admission, that every primary tissue is capable of being acted upon by appropriate stimuli, or is *sensible;* and that it possesses the additional property of *moving*, in consequence of such impression. Physiologists have, however, attempted to simplify the subject still farther, and to reduce the vital properties to one only. Such is the view of Broussais, who considers *contractility* to be the fundamental vital property of all the tissues. Adelon considers, that *sensibility* is the only living property, that must be admitted, which must carry with it the idea of motion, and is the active, motive faculty of living matter. The term *sensibility* is, however, unfortunate, in consequence of its conveying the notion of mental perception, and of such acceptation having been received into physiology to designate a function. It has, consequently, been proposed to substitute the term *excitability*, *incitability*, or *irritability*, but with the same signification. Rudolphi prefers *incitability*, (Erregbarkeit,) as not liable to the objection that may be urged against the others, of having been employed in other significations. This incitability differs in the different organs and tissues: in the muscles he terms it *irritability*, (Muskelkraft, Reizbarkeit;) in the nerves, *sensibility*, (Nervenkraft, Empfindlichkeit;) and by some physiologists, in the membranous parts it is called *contractility*, (Spannkraft, Zusammenziehungskraft.)

Such are the phenomena, which indicate the existence of the vital principle, and such the laws by which it seems to be governed. By certain physiologists, it is considered to influence solids only; by others, it has been considered to reside in the fluids also, and especially in the blood. The notion of the vitality of this fluid was espoused by the celebrated John Hunter, and to him we are indebted for many of the facts and arguments, adduced in its favour, and which have impelled the generality of modern physiologists to admit its existence. The analogy of the egg had demonstrated, that life is not restricted to substances, which are solid and visibly organized. The fresh egg, like other living bodies, possesses the ordinary counteracting powers communicated by vitality, and resists those agents, which act upon the dead egg as on other animal substances deprived of the living influence. The fresh egg may be exposed for weeks, with impunity, to a degree of heat, which would inevitably occasion the putrefaction of the dead. During the time of incubation, the egg of the hen is kept at a heat of 105°, for three weeks; yet, when the chick is hatched, the remaining yolk is perfectly sweet.

The power of resisting cold is equally great. Hunter performed several experiments, which show the power of the vital principle in resisting cold, and the influence of cold in diminishing the energy of the principle. He exposed an egg to the temperature of 17° and of 15° of Fahrenheit, and found that it took about half an hour to

freeze it. When thawed, and again exposed to a temperature of 25°, it was frozen in one-half the time. He then put a fresh egg, and one that had previously been frozen and again thawed, into a cold mixture at 15°; the dead egg was frozen twenty-five minutes sooner than the fresh. These experiments led to the legitimate inference, that the egg possessed the principle of life, and, although fluid, must have enjoyed the properties which we have described as characteristic of vitality,—of being acted upon by an appropriate irritant, and of moving responsive to such irritation.

Similar results to those obtained with the egg followed analogous experiments with the blood. On ascertaining the degree of cold, and the length of time, necessary to freeze blood taken immediately from the vessel, he found that, as in the egg, a much shorter period, and a much less degree of cold, were requisite to freeze blood that had been previously frozen and thawed, than blood recently taken from the vessel. The inference, deduced from this, was, that the vitality of recent blood being comparatively unimpaired, it was enabled to resist the cold longer than blood, whose vital energy had already been partly exhausted by previous exposure.

The fluidity of the blood, whilst circulating in the vessels, has been regarded as an additional evidence of its vitality. It is obvious, that such fluidity is indispensable, seeing that it has to circulate through the minute vessels of the capillary system, and that the slightest coagulum, forming in them, would lead to morbid derangements. Yet the blood is peculiarly liable to become solid by its constitution, and, whenever it is removed from its vessels, it coagulates. This is not owing simply to the cessation of its circulation, for if it be kept at the same temperature as in the living body, and be made to circulate with equal rapidity through a dead tube, it equally becomes solid. The cause, consequently, that maintains its fluidity, is the vital agency.

Another argument in favour of the vitality of the blood is drawn from the facts connected with its coagulation,—facts, which show, that the process is but little influenced by physical agents, and which have induced Magendie to infer,—with many other physiologists, who are but little disposed to invoke the vital agency,—"that the coagulation of the blood cannot be ascribed to any physical influence, but that it must be esteemed essentially vital, and as affording a demonstrative proof that the blood is endowed with life." It has, indeed, been attempted to show, that there are certain phenomena, which demonstrate that the vitality of this fluid increases or diminishes with the vitality of other parts of the body. When blood is drawn from a vessel it does not instantly coagulate or die; and, by observing the length of time consumed in the process, it has been thought, that we might be, in some measure, able to estimate the degree of vital energy it possesses. In diseases, where the vital action is exalted,—as in inflammation,—the blood is found to coagulate much

more slowly than in a state of health, and the coagulation itself is more perfect, whilst in diseases, that are dependent upon a diminution of the vital energy, the opposite is the fact; because, in the first case, it is presumed, the blood possesses the vital principle in a higher degree than natural, and consequently resists, for a longer period, the influence of the physical agents to which it is exposed; whilst, in the second case, it possesses the vital principle to a less degree than natural, and therefore yields sooner to the influence of those agents,—the coagulation, in all instances, being analogous to the rigidity of the muscles, which takes place after dissolution, and indicates the final cessation of vitality.

The *buffy coat* or *inflammatory crust* of the blood, called, also, *corium phlogisticum*, and *crusta pleuretica*, is a circumstance connected with the blood's life, which has been invoked by the supporters of this view of the subject. These terms are applied to an appearance of the crassamentum, which is dependent upon its upper portion containing no red particles, but exhibiting a layer of a buff-coloured coriaceous substance lying at the top, owing to the red particles, during coagulation, sinking to the lower portion of the clot, before coagulation is completed; hence the colourless state of the upper surface. At the same time, the whole of the coagulated portion is much firmer than usual. The red particles, in such case, have time to subside before the coagulation is complete, which takes place more slowly than in health; and this is conceived to be owing to the blood's possessing a higher degree of vitality,—a view which is confirmed by some experiments of Mr. Thackrah. These consisted in receiving blood, taken from the vessels of a living animal, in a full and uninterrupted stream, into different cups, and noting the time at which coagulation commenced in each. Blood, for example, was taken from a horse at four periods, about a minute and a half being allowed to intervene between the filling of each cup. In the first cup, coagulation began in eleven minutes and ten seconds; in the second cup, in ten minutes and four seconds; in the third cup, in nine minutes and thirty-five seconds; and in the fourth cup, in three minutes and twenty seconds. In another experiment, blood was drawn into three separate cups, from the veins of a slaughtered ox, the first of which was filled in the first flow; the second about three minutes afterwards; and the third a short time before the death of the animal. Coagulation commenced, in the first cup, in two minutes and thirty seconds; in the second, in one minute and thirty-five seconds; and in the third, in one minute and ten seconds. In a similar experiment, coagulation commenced, in the first cup, in two minutes and ten seconds; in the second, in one minute and forty-five seconds; and in the third, in thirty-five seconds.

Similar phenomena are found to occur in the human subject. Blood, to the amount of about a pint and a half, was taken from the arm of a female labouring under fever. A portion of this, received

into a cup on its first effusion, remained fluid seven minutes; a similar quantity, taken immediately before tying up the arm, was coagulated in three minutes and thirty seconds. Of blood, taken as in the last experiment, from the arm of a man, the first portion began to coagulate in seven minutes; the last in four. The vitality of the system, and with it the vitality of the blood, being diminished by each successive abstraction of that fluid, it coagulated or died sooner and sooner in proportion as it was previously more and more enfeebled.

It is obvious, however, that if these and other arguments lead to a belief in the vitality of the blood, they are equally favourable,—many of them at least,—to the life of the chyle, which, we have seen, accurately resembles the blood in every property, except in that of coloration; and if we admit the blood to be possessed of life, a question arises, respecting the part at which the nutritive substances, taken into the system, become converted into the nature of the being they are destined to nourish, and receive the principle of life. This must be either through the admixture of the fluids poured out from the supra-diaphragmatic portions of the alimentary canal, from those of the stomach or small intestine, or owing to the mysterious and inappreciable agency of the chyliferous radicles themselves, which separate the same fluid, chyle, from every substance that may be submitted to their action.

A reference to what has been said, on these topics, under the heads of *digestion* and *absorption*, will lead to the opinion, that no vitalizing influence is exerted on the food in the stomach and intestines, and therefore that the infusion of vitality—if the expression may be allowed—must take place in the chyliferous or sanguiferous vessels. As to the mode in which the blood obtains its vitality, great doubt must necessarily exist. The general opinion, perhaps, is, that it is obtained from the organic nerves, distributed to the inner coats of the vessels, and this idea is confirmed by an experiment of the late Mr. Thackrah, which showed, that blood, received into a dead vessel, is always more speedily coagulated than when it is retained by ligature in a living vessel; and thence he inferred, that the vitality of the vessel affects the blood, and retards its coagulation. Mr. Thackrah denies, indeed, the life of the blood, and ascribes all the evidences of it, which it exhibits, to the influence exerted by the living vessels on their contents. These are the only fluids that have been suspected to be endowed with vitality. None of the others exhibit analogous phenomena, when exposed to similar agencies.

On the whole, we are led to the conclusion, that the vital principle animates both solids and fluids, but all that we seem to know regarding it is—in the language of Dr. Barclay—"that all the organisms of animals and plants are formed out of fluids, and that in a

certain species of fluid, secreted from the parent, and afterwards inclosed in a very thin and transparent vesicle, there is a living organizing principle, which also acts upon the fluid in a way which we know not, forming out of it a regularly organized system of solids, and forming not only the rudiments of that system, but causing it afterwards to be nourished, and to grow through the medium of fluids, which are moved and distributed under the influence of this organizing animating principle."

Our knowledge being limited to this category, we are compelled to study life in its results or manifestations. These, as we have seen, constitute the science of biology or physiology.

OF DEATH.

It has wisely entered into the views of Providence, that the existence of all organized bodies should be temporary. Yet we find considerable difference amongst them, in this respect. Whilst some of the lower classes of animals and vegetables are no sooner ushered into being than a process of decay appears to commence; others require the lapse of ages for their various developements and declensions; and, as a general rule, those, in which the attainment of growth has been slow, have the period of decrease proportionably postponed; whilst, where maturity has been rapidly attained, decay as rapidly supervenes.

The ages of man are numerous and protracted. For a time, the parts of the frame, that are concerned in his developement, unceasingly deposit the necessary particles, by a process as beautiful and as systematic as it is mysterious, until ultimately the growth, peculiar to the species and the individual, is attained. At this point, the preponderance, which previously existed in the action of the exhalants over the absorbents, appears to cease. All is equality; but, ere long, the exhalants fall off in their wonted activity; the fluids decrease in quantity; the solids become more rigid; and all those changes supervene, which we have described as characterizing the decline of life, and the approach of the phenomenon, that has now to be considered.

Death is the necessary, total, and permanent cessation of those functions, by which the presence of life is characterized. This cessation may happen at all ages, from accident or disease; a few only ceasing gradually to live by the effects of age alone. Hence a distinction has been made into that kind of death which is produced by the gradual wear and tear of the organs, and that which cuts off the being prematurely from existence. The former has been termed, by some physiologists, *senile* or *natural*, the latter *accidental*. These differ considerably in their physiology; and will, therefore, require a distinct consideration.

1. *Death from old age.* The *natural period of life* is different in different individuals. It varies according to numerous appreciable and inappreciable circumstances;—the original constitution of the individual; the habits of life; the locality in which he may be situated, &c. Whilst some countries are remarkable for the longevity of their inhabitants, others surprise us by the short period that is allotted for the natural duration of life.

Blumenbach asserts, that by an accurate examination of numerous bills of mortality he has ascertained the fact, that a consider-

able proportion of Europeans reach their 84th year, but that a few exceed it; whilst, according to Fodéré, in the insalubrious region of Brenne, in France, nature begins to retrograde at from 20 to 30; and 50 years is the usual term of existence.

Haller noted one thousand cases of centenarians; sixty-two of from 110 to 120 years; twenty-nine of from 120 to 130; and fifteen who had attained from 130 to 140 years. Beyond this advanced age, examples of longevity are much more rare and less sufficiently attested; yet we have some well authenticated cases of the kind. Thomas Parr was born in 1635; married when at the age of 120; retained his vigour till 140; and died at the age of 152, from plethora—it was supposed—induced by change of diet. Harvey dissected him and found no appearance of decay in any organ. Henry Jenkins, who died in Yorkshire, in 1670, is an authentic instance of the greatest longevity on record. He lived 169 years. At this very time (Oct. 1835) a coloured woman is living, who was the nurse of Washington, and is asserted to be 168 years old.

It would not seem, that the natural period of life has differed much in postdiluvian periods. The Psalmist writes:—

"The days of our years are threescore and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow, for it is soon cut off, and we fly away." And when Barzillai excused himself for not visiting the royal palace at Jerusalem, he observed to the king:—

"I am this day fourscore years old, and can I discern between good and evil? can thy servant taste what I eat or what I drink? can I hear any more the voice of singing men or singing women? wherefore, then, should thy servant be yet a burden unto my lord the king?"

It is not easy to indicate the character of organization, which is most conducive to longevity and to health. It has been supposed, however, and with some probability, that the state of the nervous system is greatly concerned; for the pathologist looks to this part of the frame as the commencement of most if not all fatal maladies.

Generally, the aged individual sinks silently to death, in the manner described under *decrepitude*, totally unconscious of all that surrounds him. At other times, however, he preserves his sensorial powers to the last, and may be capable of locomotion; until, owing to some oppression of one or other of the vital functions during sleep, it becomes the sleep of death,—the elasticity of the organs being insufficient to throw off the oppression and resume their functions. At other times, a slight febrile irritation will be the prelude to dissolution. The great characteristic of this kind of death—as pointed out by Bichat in one of the best of his excellent productions*—is, that animal life terminates long before organic life. Death takes place in detail,—the animal functions, which connect the aged with the ob-

* *Recherches physiologiques sur la vie et la mort.*

jects around him being annihilated, long before those that are concerned in his nutrition. Death, in other words, takes place from the circumference towards the centre, whilst, in accidental or premature death, the annihilation of the functions begins in the centre and extends to the circumference. As vitality gradually recedes, in the aged, from the exterior, one of the great centres of vitality—brain, heart or lungs—stops for an instant. The powers are insufficient to restore the action, and total death necessarily ensues.

It has been an interesting inquiry with physiologists to determine the cause of death, thus naturally occurring. The opinions have been various, but such causes as affect the three great vital functions seem to be most entitled to consideration. These have been supposed to be;—*First*, ossification of the arteries, occasioning an obstacle to the free circulation of blood in the parts; *Secondly*, ossification of the cartilages of the ribs, and diminution of the capillary system of the lungs, preventing sanguification; and *Thirdly*, shrivelling and gradual induration of the nervous system, rendering it ultimately unfit for innervation, &c. These are the physical circumstances or changes, which may give occasion to the final cessation of the vital phenomena; but, after all, the difficulty remains,—and one that is insolvable,—to explain the cause why these changes themselves occur in the organs essential to vitality. We say it is insolvable, for, until we have learned the nature of life, which seems far beyond our comprehension in the present state of our knowledge, it is obviously impracticable to understand the phenomena that arise from its gradual declension and final extinction.

This kind of death, produced by the gradual declension of the powers of life, is regarded, by Dr. W. Philip, as only the last sleep, characterized by no peculiarity, in which the powers, partly from their own decay, and partly from the lessened sensibility increasing the difficulty of restoring the sensitive system, become incapable of the office, and the individual, therefore, wakes no more. We have before remarked, that there appears to us to be a difference between sleep and death, although they may tread closely on the confines of each other.

It is not common, however, for death to occur in this quiet and gradual manner. Man is liable to numerous diseases, from the earliest to the latest period of existence, many of which are of a fatal character. It was admitted by Sydenham, whose estimate cannot be regarded as more than an approximation, that two-thirds of mankind die of acute diseases; and that of the remaining one-third, two-thirds, or two-ninths of the whole, die of consumption, leaving, consequently, only one-ninth to perish from other chronic maladies, and from pure old age. How small, then, must be the number of those that expire from decrepitude simply?

2. *Accidental death.*—This term has been used, by many physiologists, to include all kinds of death that befall mankind in the course of their career, and before the natural term; the cause consisting in

the supervention of some accidental organic lesion, which arrests the vital movements before they would cease of themselves. This kind of death differs essentially from that we have been considering. The individual is here, perhaps, in the full possession of all his faculties; his organs have been, previously, to all appearance, in the most favourable condition for the prolongation of life, and his death, instead of being natural, and unperceived in its approaches by the individual himself, is usually forced and violent.

Every species of sudden death commences by the interruption of the circulation, respiration, or the action of the encephalon. One of these three functions first ceases, and the others die in succession. Each will demand a few remarks.

1. *Death beginning in the heart.*—When,—owing to fatal syncope, to wounds of the heart or great vessels, or to the rupture of an aneurism,—the heart is struck with death, the cessation of the functions is speedy. Sensation and motion are lost; respiration is arrested, and death occurs,—if the cause of the cessation of the heart's action be suddenly and sufficiently applied,—almost instantaneously. The order, in which death takes place in the different organs, is as follows. The heart failing to propel its blood, the brain no longer receives the necessary impulse for the continuance of its functions; it therefore ceases to act; the consequence of this is the death of all those organs that receive their nervous influx from it; all voluntary motion is annihilated, as well as the action of the respiratory muscles: the mechanical phenomena of respiration are, therefore, arrested; and air is no longer received into the chest. From this cause, then, the chymical phenomena of respiration would cease, were they not previously rendered unnecessary by the cessation of the heart's action. The phenomena of nutrition, secretion and calorification,—the functions of the capillaries,—yield last.

2. *Death beginning in the brain.*—In this case, owing to the loss of innervation,—as in severe injury done to the head, or in the worst cases of apoplexy,—the sensorial functions first cease, and the individual lies deprived of all sensation, volition, and mental or moral manifestation. Respiration becomes progressively more irregular and laborious, and ultimately ends. The order of death is here as follows:—the interruption of the brain's action destroys that of the voluntary and mixed muscles; the mechanical phenomena of respiration therefore cease, and then the chymical. This is followed by cessation of the heart's action, owing to the united loss of nervous influx from the brain, and the want of a due supply of blood. To the cessation of the heart's action succeeds the loss of the general circulation; and lastly, that of the functions of nutrition, secretion and calorification.

3. *Death beginning in the lungs.*—The action of the lungs may be destroyed in two ways: either the mechanical phenomena of respiration may first cease, as in hanging, strangulation, &c., where the air is prevented from reaching the lungs; or the chymical phe-

nomena may be first arrested, as when air is breathed, which does not contain oxygen, but yet can be respired for a time.

In the first case, the order of death is as follows:—the mechanical phenomena cease; to this succeeds cessation of the chymical phenomena, owing to the supply of air being cut off; the blood, not experiencing the necessary conversion in the lungs, soon stagnates in the pulmonary capillaries; for a time, however, it continues to beat, owing to the aeration effected by the residuary air in the minute bronchial ramifications; but this soon ceases in consequence of the want of supply of blood; the brain dies, and the other parts in succession.* Where the chymical phenomena first cease, the suspension of the action of the brain follows for the cause already assigned; and the mechanical phenomena of respiration are not arrested, until the nervous influx is cut off by the death of that organ.

The immediate phenomena of death and the order of their succession are easily understood, when one of the great centres of vitality is suddenly destroyed, either from accident or disease, but when death does not follow immediately, and time is allowed for a series of morbid phenomena to be established, the problem becomes much more complicated. Some organ or structure is first deranged; and, owing to the intimate connexion, which we have elsewhere seen to exist between the various functions, general derangement or irritation follows, and the individual dies, worn out by such irritation, but without our being exactly able to understand on which of the great centres that dispense vitality the malign influence has been exerted, or whether it may not have affected all equally.

In inflammation of the brain, heart, or lungs, we may presume, that the functions of these organs have been respectively annihilated by the diseased action; and that as such functions are essential to the existence of vitality, death may arise in the manner we have already described; but we frequently find the bowels affected with inflammation, or the peritoneum lining the interior of the abdomen; and the case, if neglected, is as surely attended with fatal consequences as the same morbid affection of the organs termed vital; and this in a space of time so short, as not to enable us to understand the nature of the mode of action of the lethiferous agent. But that it must exert its influence on one or more of the great centres of vitality is manifest. In many cases, the heart seems to yield first, not suddenly but gradually; the brain failing to receive its due impulse, becomes progressively unfit for transmitting the nervous influence to the muscles; insensibility gradually supervenes, until it has attained such an extent, that no nervous influence is sent to the respiratory muscles, when cessation of their action naturally ensues. Of the nature, however, of the morbid condition of the heart, thus induced by disease, we are totally ignorant. It is fashionable to say, that death is produced by irritation, but this is merely concealing our

* See the article 'Asphyxia,' by the Author, in the 'American Cyclopedia of Practical Medicine and Surgery.'

deficiency of knowledge under a term, the explanation of the agency of which comprises the whole difficulty. Adelon thinks, that the brain generally gives way first in these cases; in consequence of which the respiration is disturbed, the lung becomes engorged, the respiration difficult, and death occurs as in a case of gradual asphyxia. There is something extremely obscure in these cases. It often happens, that the intellectual manifestations and the nervous distribution to the muscles of voluntary motion will be executed, even vigorously, until a short time prior to dissolution, whilst the feeble, irregular and intermittent beat of the heart may indicate how greatly its irritability is morbidly implicated.

These remarks are chiefly applicable to death, as it arises from the numerous acute affections, which are so fatal to mankind; but it may occur, also, from those, that persist for a great length of time, and destroy after months or years of morbid irritation, as in cases of calculi of the bladder, engorgements of the viscera, &c. In these cases, likewise, death must ultimately result from the destruction of one or other of the vital functions,—respiration, circulation or innervation; but, in a manner so gradual, that it takes place nearly in the same way as in old age; except that, in all cases, it proceeds from the centre to the circumference; the great internal functions first ceasing, and afterwards their dependencies,—a difference, which explains why we are justified in attempting means of resuscitation in sudden death, whilst it would be the height of absurdity to have recourse to them where,

> "Like a clock worn out with eating time,
> The wheels of weary life at last stand still."

The renovation could only be effected by the substitution of new, for the worn out, machinery.

For some time before dissolution,—both in death from old age and from disease,—the indications of the fatal event become more and more apparent. The speech grows embarrassed; the ideas are incoherent; the hands, if raised by the effort of the will, fall inertly into their former position; the laboured respiration occasions insufficient oxygenation of the blood, and the distress excites an attempt at respiration, which the debility renders nearly ineffectual; distressing yawnings and gaspings occur to remedy the defective pulmonary action, and the whole respiratory system is in forcible and agitated motion; the teeth, at times, gnashing, and convulsive contractions occurring at the corners of the mouth. The heart becomes gradually unable to propel the blood with the necessary force into the arteries, so that the fluid ceases to reach the extremities of the body—the hands, feet, nose and ears—which grow cold, and a cold clammy moisture oozes from the vessels. In experiments on animals, the blood is found to be driven no farther than to the feet; then to the groin; afterwards, it reaches only to the kidneys, and

a kind of reflux occurs through the space along which it had previously been urged forwards. The flux and reflux now reach no farther than the diaphragm, and gradually retreat, until the blood flows back upon the heart itself, which now stops for a time, and then makes an effort to free itself from the contained fluid. The heart's action and respiration are imperfectly performed for a few times at irregular intervals, till at length the contractility of the organ is entirely gone. Respiration ceases by a strong expulsion of air from the chest,—often accompanied with a sigh or a groan, and probably arising, partly from the relaxation of the inspiratory muscles, and still more from the elasticity of the cartilages of the ribs. Hence it is that, in common language, to *expire* is synonymous with to *die*.

In cases of sudden death, the heart may continue to beat for a time after innervation and respiration have ceased. Under such circumstances, the left ventricle dies first, the obstruction to respiration cutting off its supply of blood.

For some time immediately preceding dissolution, there is usually a peculiar mixed expression of countenance,—a compound of apparent mental and corporeal suffering,—which has given occasion to its being called the *agony*. It is characterized by facial indications, which were first well described by Hippocrates, and from him called *Facies Hippocratica*. The nose is pinched, the eyes are sunken, the temples hollow, the ears cold and retracted, the skin of the forehead tense, the lips pendent, relaxed and cold, &c. The eye, during this condition, especially when dissolution approaches, is fixed and slightly elevated, being kept in that position, according to Sir Charles Bell, by the power of the brain over the voluntary muscles of the eye being lost, and the organ being given up to the action of the oblique or involuntary muscles. In this view, the state is one of insensibility, not of suffering.

Although, from the moment that respiration and circulation permanently cease, the body may be regarded as unquestionably dead, vital properties still remain in some of the organs, the presence of which is an evidence that vitality has previously and recently existed. The functions, which persist after the animal has become dead to surrounding objects, are those that belong to the *organic* class. Animal heat, for example, may still be elicited for a time, in the internal organs more especially, and it may require several hours, in death caused suddenly or speedily, by accident or disease, before the whole body becomes cold. Absorption is, also, said to have occurred after death, and the beard and hair to have grown; but it is more probable, that, in the last cases, the apparent elongation may have been owing to the shrinking of the integuments. The rectum is very frequently evacuated after dissolution; and cases have occurred where a child has been born by the contraction of the uterus after the death of the mother. The most sensible evidence, however, of the continuance of a vital property after dissolution, is

in the case of the muscles, which, as we have mentioned in another place, can be made to contract powerfully on the application of an appropriate stimulus, even for an hour or two after death. Nysten, from his experiments, inferred, that the parts cease to contract in the following order:—the left ventricle, the large intestine, the small intestine, the stomach, the bladder, the right ventricle, the œsophagus, the iris, the different voluntary muscles, and, lastly, the auricles, particularly the right auricle.

The body cools gradually at the surface, and especially towards the extremities, with a rapidity proportionate to the privation of fluids, and the coldness of the atmosphere. Whilst refrigeration is going on, the blood remains more or less fluid; and, owing to the arteries emptying themselves, by virtue of their elasticity, of their contained blood, the fluid generally accumulates in the venæ cavæ, the auricles of the heart, and the vessels of the lungs. By virtue of its gravity, it collects also in the most depending parts, occasioning cadaveric hyperæmiæ, *sugillations* or livid marks, which might be mistaken for bruises inflicted during life; but may generally be distinguished from them by attention. It will be readily understood, that the situation of the blood in the vessels may differ somewhat according to the vital organ which first ceases its functions. If the action of the right heart stops, the lung may be empty; if the lung or left heart ceases, the lung and the right side of the heart—with the vessels communicating with it—may be surcharged with blood, whilst the organs of the corporeal circulation may be almost empty.

During the progress of refrigeration, and especially soon after death, the muscles are soft and relaxed, so that the limbs fall into that position to which the force of gravity would bring them; the eyes are half open; the lips and lower jaw pendent, and the pupil dilated. When the body, however, is cold, the blood is coagulated, and white or yellowish coagula exist, especially in the cavities of the heart, which were at one time supposed to be morbid formations, and termed *polypi.* They take the shape, more or less, of the cavity in which they are found. Lastly, the muscles become firmly contracted, so that no part can be moved, without the application of considerable force; and, in this state, they continue until the natural progress towards putrefaction again softens their fibres. This has been regarded by physiologists as arising, like the coagulation of the blood, from the last exertion of that residue of vital power, which the body retains after the period of apparent dissolution. With more propriety, perhaps, it may be assigned to physical alterations taking place in the organs, owing to the total loss of those powers, which were previously antagonists to such changes.

It might seem from the previous enumeration of the signs of death, that no difficulty could possibly arise in discriminating between a living and a dead body. Cases have, however, occurred, where such difficulty has been great and perplexing. Many of the

signs may exist, and yet the person be merely in a state of suspended animation; and in certain instances it has even been considered advisable to wait for the manifestations of the putrefactive process, before the body should be consigned to the grave. The following case, given by Dr. Gordon Smith, strongly exhibits the embarrassment that may occasionally arise. A stout young man had been subject to epilepsy, which became combined with madness. On this account, it was necessary to remove him to a private asylum in the neighbourhood of London, where he died suddenly, in a violent epileptic paroxysm. The body was removed to the residence of his friends, soon after death, when the necessary preparations for interment were made. On paying attention to the corpse it was found, that the limbs were quite pliable; that the eye was neither collapsed nor glazed; and that the whole features retained their full natural appearance as during life. A surgeon, who, for years, had been in the habit of attending him, was sent for; and although he could find no indications of vitality, he prudently recommended, that the interment should not take place until decomposition had begun to manifest itself. In the course of two or three days, appearances still continuing the same, a physician was called in, who concurred in the recommendation that had been already given. Fifteen days from the supposed time of his death had elapsed, when Dr. Smith's informant had an opportunity of inspecting the body. At this time, the countenance retained the appearance described, but the eye seemed beginning to sink, and some degree of lividity had commenced on the surface of the abdomen. The joints were still flexible. At this time, a very eminent professor of anatomy viewed the body, and, considering the hesitation that had prevailed to be altogether groundless, he appointed the following day to examine it internally. The head was accordingly opened, and a considerable extravasation of blood found in the posterior part of the cranium, between the skull and dura mater and between the membranes and substance of the brain. No serum was detected in the ventricles; but the brain itself was remarkably hard. This was sixteen days after death. On the following day, the body was interred. A clamour now arose amongst the neighbours, that he had been prematurely handed over to the anatomist. The body was exhumed; an inquest was held; and the evidence of the medical gentlemen demanded. The jury, of course, returned a verdict of "apoplexy."

It may hence become a matter of medico-legal inquiry to verify the existence of death, in cases where doubt prevails, from the person being in a state of apparent death,—natural or assumed.

Perhaps the most singular case on record, of suspension of two of the most important of the vital functions, occurred to the distinguished John Hunter. In the year 1769, being then forty-one years of age, of a sound constitution, and subject to no disease, except a casual fit of the gout, he was suddenly attacked with a pain

in the stomach, which was speedily succeeded by a total suspension of the action of the heart and of the lungs. By violent exertion of the will he occasionally inflated the lungs, but over the heart he had no control whatever; nor, although he was attended by four of the chief physicians in London from the first, could the action of either be restored by medicine. In about three-quarters of an hour, however, the vital actions began to return of their own accord, and in two hours he was perfectly recovered. "In this attack," says his biographer, Sir Everard Home, "there was a suspension of the most material involuntary actions, even involuntary breathing was stopped; whilst sensation, with its consequences, as thinking and acting, with the will, were perfect, and all the voluntary actions were as strong as ever."

At one period it was universally credited, that substances could be administered, which might arrest the whole of the vital functions or cause them to go on so obscurely as to escape detection. This erroneous popular notion is exhibited, in the description of the action of the drug, administered by Friar Lawrence to Juliet:—

> "Take then this phial,
> And this distilled liquor drink thou off;
> When presently thro' all thy veins shall run
> A cold and drowsy humour, which shall seize
> Each vital spirit; for no pulse shall keep
> His natural progress, but surcease to beat.
> No warmth, no breath shall testify thou livest;
> The roses in thy lips and cheeks shall fade
> To paly ashes; the eyes windows fall
> Like death, when he shuts up the day of life;
> And in this borrow'd likeness of shrunk death,
> Thou shalt continue two-and-forty hours,
> And then awake as from a pleasant sleep."

Death may also be feigned for sinister purposes. The author recollects a body having been brought in a sack to the house of Mr. Brookes, the distinguished anatomist of London, the vitality of which was detected by the warmth of a protruded toe. It was that of a robber, who had chosen this method of obtaining admission within the premises.

The celebrated case of Colonel Townshend exhibits the power occasionally possessed over the vital functions; and Dr. Cleghorn, of Glasgow, knew an individual, who could feign death, and had so completely the power of suspending, or at least of diminishing, the action of the heart, that its pulsations were imperceptible.

Lastly, the character of the death, as to violence or gradual extinction, is often exhibited in the physiognomy of the dead. Where it has taken place during a convulsion, or by agents that have forcibly and suddenly arrested respiration or innervation, the countenance may be livid, the jaws clenched, the tongue protruded and caught between the teeth, and the eyes forced, as it were, from their sock-

ets; but usually in death from old age, or even from acute and tormenting disease, any distortion or mark of suffering, that may have existed prior to dissolution, subsides after the spirit has passed, and the features exhibit a placidity of expression, singularly contrasting with their previously excited condition. For effect, however, the poet and the painter suit their descriptions of death to the character of the individual whom they are depicting. The tyrant falls convulsed and agonized, whilst the tender and delicate female is described to have progressively withered, till

> "At last,
> Without a groan, or sigh, or glance to show
> A parting pang, the spirit from her past:
> And they who watch'd her nearest could not know
> The very instant, till the change that cast
> Her sweet face into shadow, dull and slow
> Glazed o'er her eyes—the beautiful, the black,
> Oh! to possess such lustre, and then lack."
>
> BYRON, *Don Juan*, Canto IV.

Warwick's description of the frightful physiognomy of Duke Humphrey, after death from suffocation, exhibits some of this poetical license:—

> "But see his face is black and full of blood;
> His eyeballs farther out than when he liv'd,
> Staring full ghastly like a strangled man:
> His hair uprear'd, his nostrils stretch'd with struggling:
> His hands abroad display'd, as one that grasp'd
> And tugg'd for life, and was by strength subdu'd.
> Look on the sheets, his hair you see is sticking:
> His well-proportion'd beard made rough and rugged,
> Like to the summer's corn by tempest lodg'd.
> It cannot be but he was murder'd here:
> The least of all these signs were probable."
>
> KING HENRY, VI. P. 2. Act III.

How different is this picture from that of the countenance of the young being, who has gradually sunk to death in the manner above described. The beauty is unextinguished, and the paleness and lividity of death have taken the place of the colours of life; yet the wonted physiognomy may remain:—

> "Hush'd were his Gertrude's lips! but still their bland
> And beautiful expression seem'd to melt
> With love that could not die!"
>
> CAMPBELL.

Perhaps one of the most beautiful and accurate pictures, drawn by the immortal Byron, is his description of the serenity of countenance observable in most fresh corpses; an expression, which, by

association, is deeply affecting, but not without its consolation to the friends of the departed:—

He, who hath bent him o'er the dead,
Ere the first day of death is fled;
Before decay's effacing fingers
Have swept those lines where beauty lingers;
And mark'd the mild, angelic air,
The rapture of repose that's there:
The fix'd yet tender traits, that streak
The languor of the placid cheek;
And but for that sad, shrouded eye,
That fires not,—wins not,—weeps not now;
And but for that chill, changeless brow,
Where cold obstruction's apathy
Appals the gazing mourner's heart,
As if to him it could impart
The doom he dreads, yet dwells upon:
Yes, but for these and these alone,
Some moments, ay, one treach'rous hour,
He still might doubt the tyrant's power.
So fair, so calm, so softly seal'd
The first, last look by death reveal'd.

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* ii. refers to the Second Volume.

T.

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